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A LEAF AND CORM DISEASE OF GLADIOLI CAUSED BY BACTERIUM MARGINATUM [1]

By LUCIA MCCULLOCH

Assistant Pathologist, Laboratory of Plant Pathology, Bureau of Plant Industry, United States Department of Agriculture

INTRODUCTION

The disease caused by *Bacterium marginatum* probably occurs to some extent wherever gladioli are grown, but in some regions it does not attract much attention because the signs of disease are inconspicuous or entirely lacking. In other localities with more favorable conditions for the parasite, the loss may be considerable. The parasite in viable and pathogenic condition is carried over on the corms from season to season. The lesions being sometimes small, may escape detection; therefore corms apparently normal may be the means of carrying the disease to various parts of the country where, if conditions favor its development, it may become a menace to gladiolus culture.

The bacteria causing this disease have been isolated from gladioli grown in Florida, California, Virginia, Pennsylvania, Indiana, Michigan, Maryland, and the District of Columbia. This disease was first studied by the writer in 1913 when a commercial grower in the Middle West sent to the United States Department of Agriculture a number of infected plants, and stated that the disease was causing considerable loss in his fields. From these plants an organism was isolated which proved to be definitely pathogenic and produced lesions on inoculated gladioli identical with those on the original host. The cultural characters of the organism were also determined at this time.

In 1920 the disease was observed on gladioli growing in the District of Columbia and Virginia. Plants grown on the same land and from corms produced in 1920 were under observation from 1921 to 1923 and all showed a recurrence of the disease.

Several gladiolus farms in Central Michigan were examined by the writer in September, 1922, and the disease found generally prevalent but, according to the growers, it was less severe than in some previous years.[2]

A reference to laboratory notes indicated that an organism with similar characters was isolated from diseased gladioli received in April, 1910, from California. In July, 1922, the writer found inconspicuous lesions of this disease on gladioli in a florist's shop in Los Angeles, Calif. The disease was not found at that time in the plantings about Los Angeles.

A brief description of this disease and of the causal organism (*Bacterium marginatum*) was published in 1921 (*1*).

In Phytopathology (*2*) there is an abstract of a paper read at the Cincinnati meeting. This abstract deals not only with the disease caused by *Bacterium marginatum* but also with another bacterial leaf blight of gladioli (*3*) caused by *Bacterium gummisudans*.

DESCRIPTION OF THE DISEASE

The lesions may appear on any part of the leaf but are usually confined to the fleshy, basal region, and it is here that the serious damage occurs. Tiny specks of bright reddish-brown color, slightly elevated and usually in considerable numbers, are the first visible signs of the disease. By enlarging and coalescing these spots produce large necrotic areas, in which all the parenchyma tissue is destroyed (Pl. 1). When infections are more isolated, very typical lesions are produced. The tiny speck enlarges to a circular, or more often, elongated spot; the center is sunken, dark-brown, or almost black with the margin slightly elevated and

[1] Received for publication June 25, 1924—issued January, 1925.

[2] Thanks are given to H. C. Oven of Ovid, Mich., for cooperation in collecting specimens of diseased plants, supplying healthy corms for experimental purposes and for many helpful suggestions.

darker in color. (Sanford's brown to hazel brown for lightest color and mahogany brown to black for the darkest (7).[3] These spots look quite like burned places, the margins especially resembling charcoal. The fibrovascular bundles are not primarily attacked and stand out prominently in the sunken areas. Ordinarily the infected tissues are rather dry and firm, but if the plants are kept under unusually moist conditions the disease progresses rapidly like a general soft rot and without the brightly colored, definitely outlined spots.

Infection is most general on the lower parts of the leaves, from ground level up to a height of 6 to 8 inches. Under favorable conditions the spots enlarge rather rapidly and soon destroy large areas of the soft tissues. The whole thickness of the leaf is involved, and protected from drying influences by the outer leaves, the rot progresses more rapidly in the interior and has here more of the appearance of a soft rot. Plants showing but slight exterior signs of disease often show a surprising amount of rot when the leaves are pulled apart. The underground stem-like part just above the corm usually shows evidence of the disease, either as tiny reddish-brown spots or as a more extensive rot.

So long as the fibrovascular system functions the leaf parts above the lesions remain normal. The vascular system seems not to be directly affected, but eventually the vessels become blocked with a brownish, gum-like substance and the leaf parts above die. Sometimes only a narrow, dry, brown streak is present in a leaf; more often the whole leaf is brown and dry. In some cases one or more brown leaves are seen in plants otherwise normal in appearance (Pl. 2).

In cases of severe infection, with destruction of large areas of cellular tissue, the whole plant falls over, bending at or near the ground level. At this stage of the disease the basal parts are dull brown in color, fibrous, and soft-rotted or dry-rotted, depending on the amount of moisture present (Pl. 1, A).

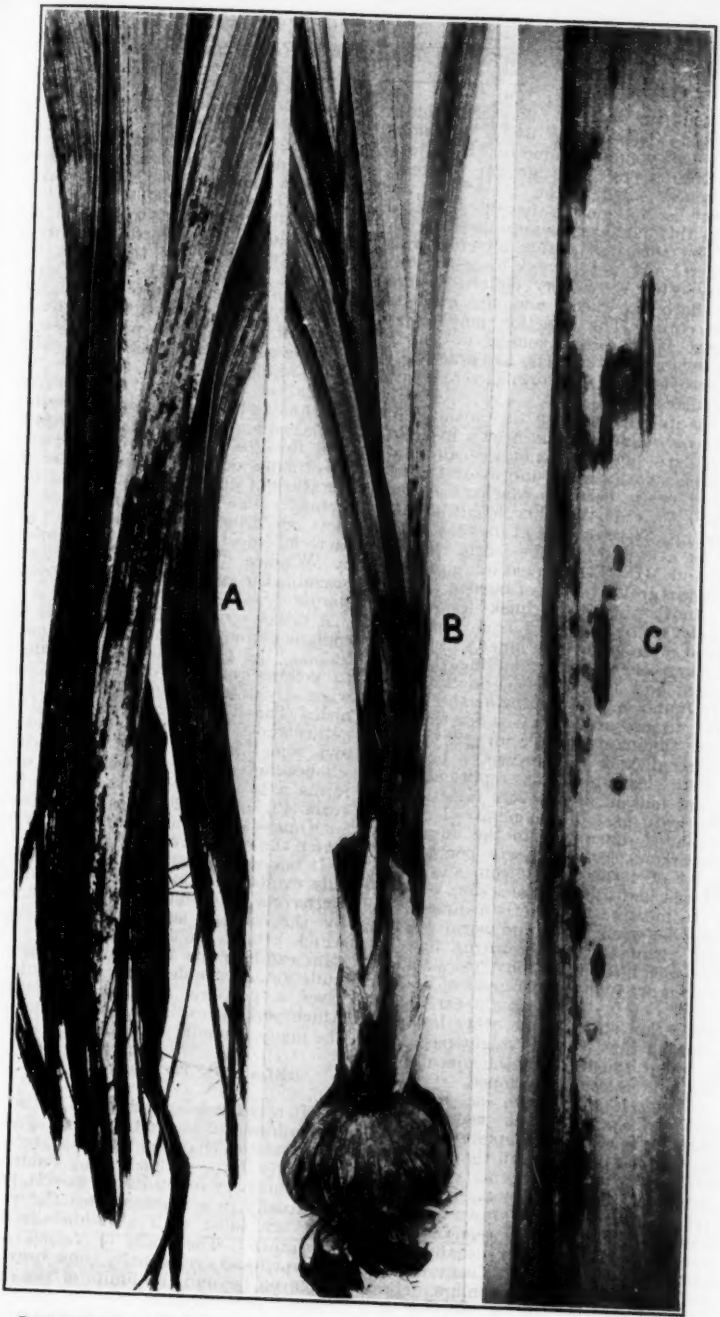
The upper parts of the leaves have but few infections. These remain small and cause no damage except to the appearance of the foliage (Pl. 4, F).

The date of the appearance of the disease depends largely on the temperature and moisture conditions. Warm, moist weather seems a necessary factor for infection. In the vicinity of Washington, D. C., the earliest noted appearance was June 6, 1921, on the variety America. The plants, about 1,300 in number, were from corms that had remained in the ground all winter. In 1920 the plants in this bed were moderately infected with the disease. The 1921 shoots came up early in April and remained entirely normal, clean, and vigorous until June 6, when the first small but typical spots were found. Isolation plates from these spots produced the characteristic bacterial colonies. On June 8, about 20 per cent of the plants in this bed showed lesions on the lower leaves. After June 6, the disease gradually increased in number of plants infected and severity of attack. Many outer leaves and a few whole plants rotted off near the ground level. Plants with average or slight infection produced fine flower spikes. It was observed that occasionally of two plants springing from the same corm one would be infected, the other entirely free from infection. An adjoining bed of about 1,000 plants from newly purchased corms (varieties Augusta and Mrs. Francis King), growing on soil not recently, if ever, planted to gladioli, had on June 8, no indication of disease. Later in the season a few definite cases of the disease were found in this bed.

In the fall of 1921 the corms from both beds were dug and placed in storage. In the spring of 1922 they were planted in the plats used the two previous seasons. The early growth was normal but as the season advanced the disease appeared and increased in severity until by September practically all the plants were more or less affected. Out of about 1,400 (all that survived of the two lots) only 13 showed no outward sign of the disease. In 1923 the disease was again prevalent in the same plats of ground, planted with old and some new stock, but owing to cool weather in the early part of the season the disease was not evident until early July.

In an examination of a large planting in Michigan, where this disease had caused more or less trouble for the past 10 years, it was noted that the leaves of young stock were usually entirely free from the disease and that the older plants were affected in proportion to their age. This seems to indicate that a diseased plant carries the disease along from year to year, the disease increasing in severity until the plant succumbs. The grower stated that he believed this disease to be the eventual

[3] Reference is made by number (italic) to Literature cited, p. 117.



BACTERIUM MARGINATUM ON GLADIOLI

PLATE 1

A.—Leaves entirely rotted at base. ×½.
B.—Outer leaves removed to show interior rot. ×½. A and B, natural infections collected and photographed July 21, 1920. Washington, D. C.
C.—Natural infection on leaf. ×4.

cause of the death of many of the older plants. There seems to be no generally used common name for this injury to the leaves. One grower suggests "neckrot" and as the "neck" of the plant is the most noticeably affected part this name seems appropriate.

The corms of plants affected with neckrot are not always diseased, but they often show very definite lesions on both the husks and the body of the corm. The infection may be so slight as to escape general notice, or so severe that the husks are practically destroyed and the corm covered with circular sunken spots.

In its early stages the husk lesion is pale yellow or pale brown in color, circular, oval or sometimes an elongated streak, with unbroken tissues. The color becomes darker, almost black; the husk splits longitudinally and also disintegrates at its base where it is attached to the corm (Pl. 3, A and B). The ragged margins have the texture and color of burned tissues.

Another type of husk lesion less likely to be observed is a thickened band of tissue on the inner side of the husks, near and surrounding the terminal bud (Pl. 3, H). Such lesions are found only by removing the husks. The tissues are several times the normal thickness, brittle or gritty like charcoal, and dark brown to black in color. Probably this represents the lower margin of a severe infection on the leafy part of the plant which has extended downward to the husk as a continuous lesion. Forty per cent of a lot of corms taken from storage in March had this type of lesion.

In most cases there is a direct relation between husk and corm lesions, the corm infection occurring just below the husk infection. Occasionally lesions are found under areas of healthy husk, but in these cases a careful examination shows some other lesion so situated that bacteria might pass from it under the husk to the place where the hidden lesion developed.

Corm lesions begin as definitely outlined, pale yellow water-soaked, circular spots. The epidermis shows no visible injury and all the tissues are firm. The color deepens, varying on corms of different colors, from light yellow-brown to dark brown or almost black. The epidermis remains intact over some lesions, but usually it becomes split or broken. Eventually the corm lesion becomes a shallow depression surrounded by a definite and somewhat elevated margin (Pl. 3, G). These depressions are usually only 2 to 6 mm. in diameter, but, when numerous, they coalesce and form large, irregular sunken areas. The pits do not extend deeply into the flesh of the corm and are rather easily removed, leaving a clean, saucer-shaped cavity lined with healthy cells.

Gladioli are subject to several diseases which produce corroded spots or pits on the surface of the corms, and although those caused by *Bacterium marginatum* are usually quite characteristic, it is realized that injuries due to other agents may produce lesions having a general appearance not unlike those which numerous isolation and inoculation experiments have proved to be caused by *Bacterium marginatum*.

The name scab is a good descriptive term for these lesions on the corms. This name occurs frequently in the literature of gladiolus disease and it is probable that in many instances the spots described were due to this bacterial infection. Some illustrations by Wallace (*11*) and others closely resemble the spots caused by *Bacterium marginatum*.

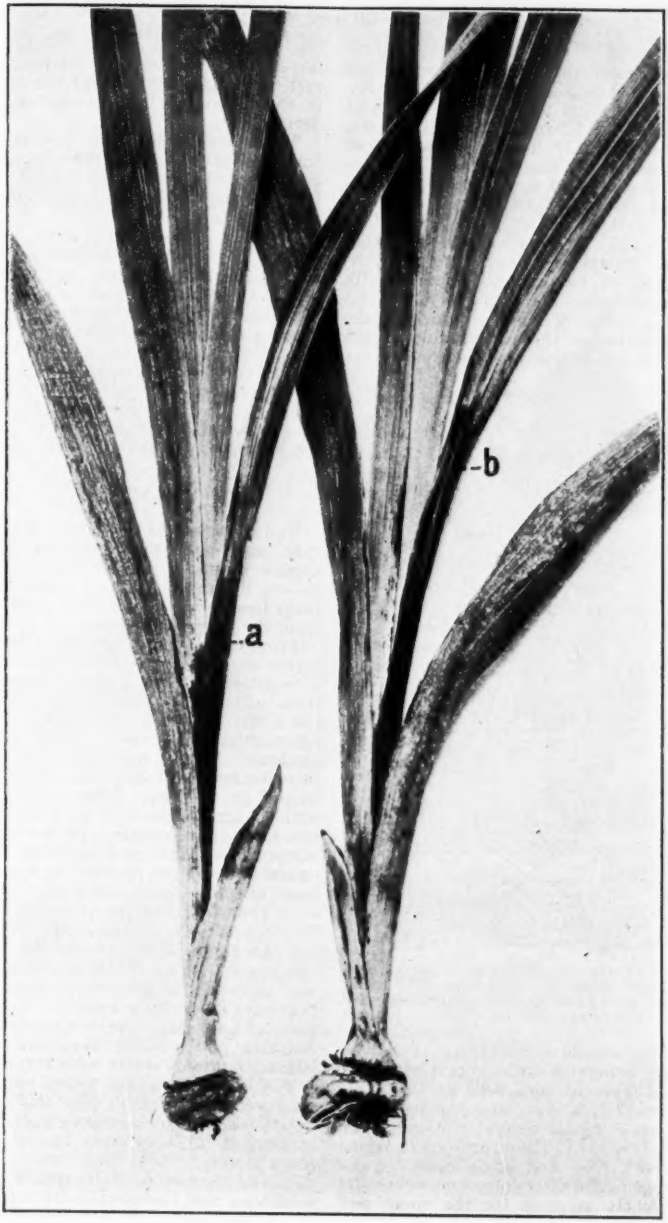
A rather striking phenomenon is the copious gummy exudate from the corm lesions. At first colorless, it changes to yellow-brown or dark brown, and when dry is brittle and shiny like varnish. The diseased husks are glued together and to the corm by this exudate and sometimes even the surrounding soil becomes impregnated with gum and forms a mass closely attached to the corm (Pl. 3, E and F). Just under each such mass of soil are the lesions from which the exudate flowed (Pl. 3, G).

It has not been determined whether this exudate is due to the action of *Bacterium marginatum* alone or aided by the various secondary organisms which attack the injured tissue. No gum exudes from leaf lesions or from quite young corm lesions. The exudate gives a positive reaction for sugar, which perhaps explains the presence of the many secondary organisms.

RELATION TO HOST TISSUE

Microscopic examination of sections of fresh and of stained material of leaf tissue shows that the bacteria are active only in the parenchyma. Bacteria have not been found in the vessels, but eventually in a diseased area the vessels are filled with a reddish-brown substance. The walls of vessels are browned and occasionally show browning even beyond the limits of the discolored parenchyma.

Bacteria enter through the stomata but it has not been proved that this is the only mode of invasion. Stomata



BACTERIUM MARGINATUM ON GLADIOLI PLATE 2

Natural infections. Collected and photographed June 20, 1922. Washington, D. C. +¼. Extensive rot at the base of *a* and *b* has caused these leaves to become dead and brown. The leaves just above *a* and *b* have isolated infection areas. (Red spider injury on older leaves.)

are present on both surfaces of the husks and on the epidermis of the corm. In leaf lesions the bacteria are most often found in small compact masses, sometimes only in a small area near the center. While numerous, they are not so abundant as in some other bacterial diseases. From fresh sections they ooze out only moderately and do not readily distribute in the mounting fluid. Capsules have been demonstrated on bacteria obtained directly from the plant and it is likely that this viscid covering tends to reduce the distribution of the bacteria both in the tissues and in the mounting fluids.

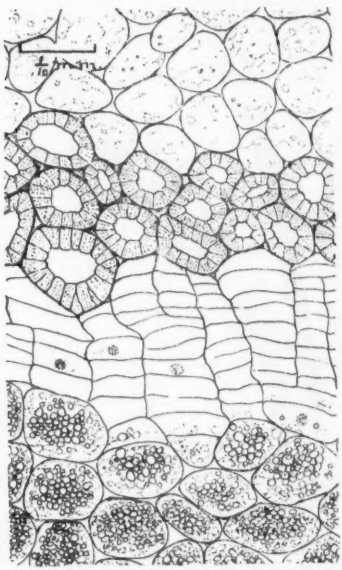


FIG. 1.—Camera lucida drawing of a section made through the base of a corm lesion. The healthy cells, full of starch, are separated from the diseased cells by cork and stone cells

Microscopic examination of the lesions removed from corms shows a wide layer of cork cells at the back, 10 to 12 cells deep, and just inside the cork are found several rows of stone cells (fig. 1). These protective layers of cork cells and stone cells are developed soon after infection occurs and evidently account for the small size and slight depth attained by the lesion. The ridge surrounding the lesion is formed by the out cropping of these cells. In the central part of the infected area are collapsed cells and a gummy substance, amber to brown in color, according to age. As in the leaf lesions, the bacteria are found in rather restricted areas near the center of the pit and not far below the epidermis.

These succulent corm lesions are subject to invasion by other organisms, both bacteria and fungi. Leaf and husk lesions are much less liable to secondary infections.

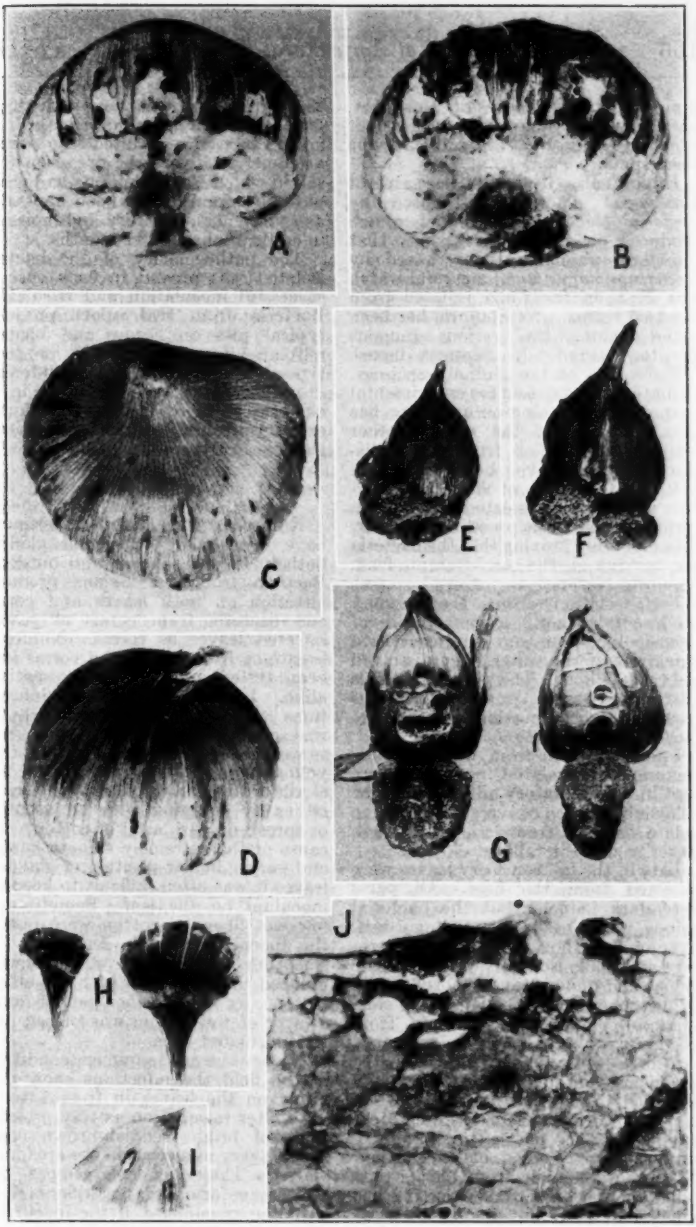
Growing corms which were inoculated with *Bacterium marginatum* had typical lesions 1 to 4 mm. in diameter 4 weeks later. The epidermis was intact and not visibly sunken though some of the cells just below the surface were brown and collapsed. Most of the interior cells were fairly normal in appearance and were still full of starch. The cork tissue at the back of the lesion was well developed but the stone tissue was barely discernible.

ISOLATION

The organism which causes this disease has been isolated repeatedly by means of agar poured plates from leaves, flower stalks, and corms, both from fresh and dry material, and also from the gummy exudate.

From either new or old infections on leaves and husks there is no difficulty in isolating *Bacterium marginatum*, but from any except recent corm lesions the plates are likely to have a discouraging number of various sorts of organisms. A corm spot that is still pale in color and with unbroken epidermis should be selected. From such spots with a sterilization of 2 to 3 minutes, absolutely pure cultures of *Bacterium marginatum* have been secured. The causal bacteria are present, in some at least, of the old lesions on corms, as has been proved by isolation experiments, but they do not often succeed in producing characteristic colonies in the isolation plates because of the great number and vigor of the secondary organisms that have invaded the lesions. Various sorts of bacterial colonies appeared in isolation plates made from old corm lesions, but only rarely were there any yellow colonies. If the yellow colonies produced looked at all like *Bacterium gummisudans*, which causes a leaf blight of gladioli (*3*), they were investigated more closely. None was ever found with the characters of *Bacterium gummisudans*, and inoculation experiments (see p. 167) further prove that *Bacterium gummisudans* is not connected with these corm lesions.

In a field where both *Bacterium marginatum* and *Bacterium gummisudans* occur, both diseases have quite often been found on the foliage of the



BACTERIUM MARGINATUM ON GLADIOLI PLATE 3

A and B.—Corms with husks badly infected and lesions on the body of the corm. ×⅞.
C and D.—Typical moderate infection of outer husks. ×⅞.
E and F.—Masses of soil held together and to the corms by the dried exudate from the lesions. ×¾.
G.—Soil masses removed to expose the lesions. ×¾.
H.—Husk lesions. Thick, crusty tissues on inner side of husks. ×¾.
I.—Lesions on thin inner husk. ×¾.
J.—Section through a corm lesion. The fine-grained cloudy part is full of bacteria. ×about 160.

same plants. Because of this fact, particular care was taken to discover which, if either, was responsible for the corm spots.

Having also in mind the hard-rot disease of gladioli (*4*) caused by *Septoria gladioli* Passer and which produces on the corms lesions that sometimes resemble those caused by *Bacterium marginatum*, a careful watch was kept on the fungi isolated from diseased corms. No Septoria has been found among the various fungous growths secured. No Septoria disease has occurred on the gladioli, seedlings, or mature plants, used for experimental purposes in Washington and none has been observed in the various other plantings of gladioli from which diseased corms have been obtained.

Virulent colonies of *Bacterium marginatum* have been isolated in July from corms harvested the preceding October, thus definitely proving that the bacteria can survive on the stored corms from season to season.

For isolation from the gummy exudate from corm lesions, pieces of clean-looking gum were selected, rinsed quickly in sterile water, then dissolved in beef boullion. The plates from this unsterilized gum produced various growths, a fair proportion of which were *Bacterium marginatum*.

Infected leaves from which typical bacteria were isolated in August were kept in the laboratory all winter. The following March several efforts to isolate bacteria from lesions on these leaves resulted in failure.

Late in the fall some dry leaves were collected from the field. All parts were dark in color but the bacterial lesions could easily be distinguished. Examination showed that the bacteria were in small, isolated pockets in the lesions and under pressure oozed out in a thick mass. Typical *Bacterium marginatum* colonies were secured from this material.

Efforts were made to isolate the organism from plant parts that had remained in the field all winter. All the soft tissues had disintegrated, leaving only the flower stalks and the fibrovascular bundles of the leaves. Platings were made from black spots found on the stalks and from fibrous remains of leaves but among the great numbers of colonies that appeared in the plates there was none that resembled *Bacterium marginatum*.

No success has resulted from several attempts to isolate the organism from soil in which diseased plants had grown but the organism has been kept alive and virulent in both dry and moist soil in culture tubes for 11 months.

The pathogenicity of the bacteria isolated was proved in each case by successful inoculation and reisolation. Bacteria from leaf spots produced typical pits on corms and bacteria reisolated from these corms produced typical leaf infections. No difference in pathogenicity has been noted in the bacteria obtained from leaves, husks, or corms, from the different varieties of gladioli, or from different localities.[4]

INOCULATIONS

Numerous inoculation experiments have been made on sound gladioli, both in the greenhouse and outdoors. Bacteria from leaf lesions produced infection on both leaves and corms, and bacteria from corms as readily infected leaves as corms. Numerous isolations from leaves and corms have been tested and all seem essentially alike. In some of the early inoculations needle pricks were made, but it was soon found that it is not necessary to wound the epidermis. Bacteria from young agar cultures were diluted in sterile water and applied to the leaves either by spraying with an atomizer or spread on with a bit of cotton. Because of the extremely smooth surface and perpendicular position of gladiolus leaves it was often difficult to keep the inoculum on the leaf. Sometimes a few wet fibers of cotton were put on the inoculated areas. In others the smoothness of the leaf was somewhat reduced by rubbing with a bit of cotton. In dry weather, out of doors, a layer of wet cotton was placed over the inoculated area.

Under average summer conditions in the field the infections show definitely on the leaves in from 7 to 12 days after inoculation as tiny, isolated spots of bright reddish-brown color, usually very numerous in the area inoculated. These by enlargement and coalescence form the larger lesions (Pl. 1).

In the greenhouse, if the inoculated plants were kept for the first 24 hours

[4] Dr. Ivan C. Jagger isolated *Bacterium marginatum* from gladioli grown in Florida from corms obtained from a New York firm. The disease appeared during the summer rainy season. Doctor Jagger states:

During four years spent largely in Florida I examined several small plantings of gladioli, and invariably found no leaf spots. Generally gladioli are planted out in the late fall or early winter so that they come into bloom rather early in the spring, when the weather is quite generally dry and unfavorable for leaf blights. My planting, which developed bacterial leaf spot, was made much later in the season than is favorable for best results.

in a moist case, the infection showed plainly in from 3 to 5 days. If moist conditions were continued, a rather extensive soft rot occurred, the tissues becoming gray-green and water-soaked.

Sterilized soil, sterile water, and a pure culture of the bacteria were mixed, then spattered over the leaves of healthy plants. No effort was made to wound the epidermis. This inoculum was kept moist for 12 hours by placing the plants in a moist case. The plants were then returned to the open bench where the usual watering quickly washed off the soil particles. Tiny spots due to the bacteria were noted on the sixth day and by the ninth day the largest spots were 2 mm. in diameter. There were 200 or more spots on the inoculated side of the leaves. The opposite side where no inoculated soil had been placed had a few scattered infections. The spots enlarged, coalesced, and caused the death of the inoculated leaves.

Soil from outdoor beds where diseased gladioli had grown the previous season has been used to inoculate gladioli. The soil was moistened with sterile water and spread in a thick layer over the lower leaf parts of vigorous greenhouse plants or by placing on the leaves a layer of cotton soaked with the soil and water mixture. The moist condition of the soil inoculum was retained for several days by keeping the plants in a moist chamber. This experiment was tried in May, 1922, in April, 1923, and in March, 1924. No infections resulted from any of these inoculations.

Garden soil from plats where the gladiolus disease had occurred for three seasons was brought into the greenhouse in January and healthy gladiolus corms were planted in it. These corms had the husks removed and the surface sterilized by a 15-minute treatment in a mercuric chloride, 1–1000, solution. Examination in June showed definite and typical spots on the new corms and isolation plates from both husk and corm spots gave pure cultures of *Bacterium marginatum*. Control plants in sterile soil showed no signs of infection.

On corms the lesions produced by inoculation were slower in growth than those on leaves. Development may be more rapid under more favorable conditions. The quickest results were secured on young, growing corms by removing enough soil to expose most of the corm but without disturbing any of the roots. The soil particles were washed off, bits of the husk were loosened and lifted so that bacteria could be placed directly on the uninjured surface of the corm. The husks were replaced and the corm again covered with the soil. Typical brown pits, 1 to 4 mm. in diameter, were found 4 weeks after such inoculations and pure cultures of *Bacterium marginatum* secured from them.

In other corm inoculations the bacteria were placed on the husks or the soil was thoroughly wet several times during the growing season with water containing bacteria. Both of these methods gave infections but they were slower in developing than the preceding.

That mature corms are less subject to infection than young, growing corms was shown in the following experiment. Seventy healthy, husked, and sterilized corms were planted in pots in sterilized soil. Most of these were inoculated with pure cultures of *Bacterium marginatum*, others with crushed lesions from diseased corms. These dry lesions taken from corms harvested several months previously were pounded in a mortar and softened with water. In each case the inoculum was poured over the uninjured corms when planted. The inoculation was repeated several times during the early growing period by pushing the soil away and pouring the inoculum over the corms. When harvested only 13 of the 70 old corms showed signs of infection. In 31 pots of this lot of 70 the inoculation was resumed during the growth of the new corms and 27 of the new corms (of the lot of 31) had typical husk and corm lesions from which the bacteria were isolated and their pathogenicity proved.

Fifty-two healthy, husked, and sterilized corms were planted in pots in sterile soil. Pure cultures of *Bacterium gummisudans* (*3*), also fresh leaf lesions caused by that organism, were used to inoculate these corms. The inoculum was applied and repeated at intervals as in the preceding experiment. When mature a few typical husk spots and corm pits were found on three of the new corms. Isolation plates were made from all three and in each case *Bacterium marginatum* was secured but not a single colony of *Bacterium gummisudans*. These 52 plants were grown in the same greenhouse and at the same time as those inoculated with *Bacterium marginatum*. They were on separate benches and care was exercised to avoid contaminations. It is not known just how these three corms became infected with *Bacterium marginatum*.

Twelve healthy corms, husked, sterilized, and planted in sterile soil were

inoculated with cultures of various fungi that had appeared in isolation plates inoculated from corm lesions. The inoculations were repeated, as in the preceding experiments, but neither the old nor the new corms became infected.

Introducing *Bacterium marginatum* into wounds made in mature corms did not produce any rot. This was tried three times with different degrees of heat and moisture, using varieti s known to be susceptible. There wa no reaction beyond a slight browning and the formation of an imperfect layer of cork. These corms were then planted and produced normal plants. Tests showed the juices of these gladiolus corms to be very acid. It is possible that the bacteria coming into direct contact with large amounts of the acid juice from the wounded tissues were not able to grow.

Potato tubers were copiously inoculated with this organism but no trace of rot resulted.

MORPHOLOGY

Obtained directly from the host the organism is at first sluggishly motile but after a few minutes it becomes more active. Staining with carbol fuchsin shows rods of varying sizes, 0.8 to 1.8 by 0.5 to 0.6μ. Many are so short as to resemble cocci. The rods are rounded at the ends and occur singly and in pairs.

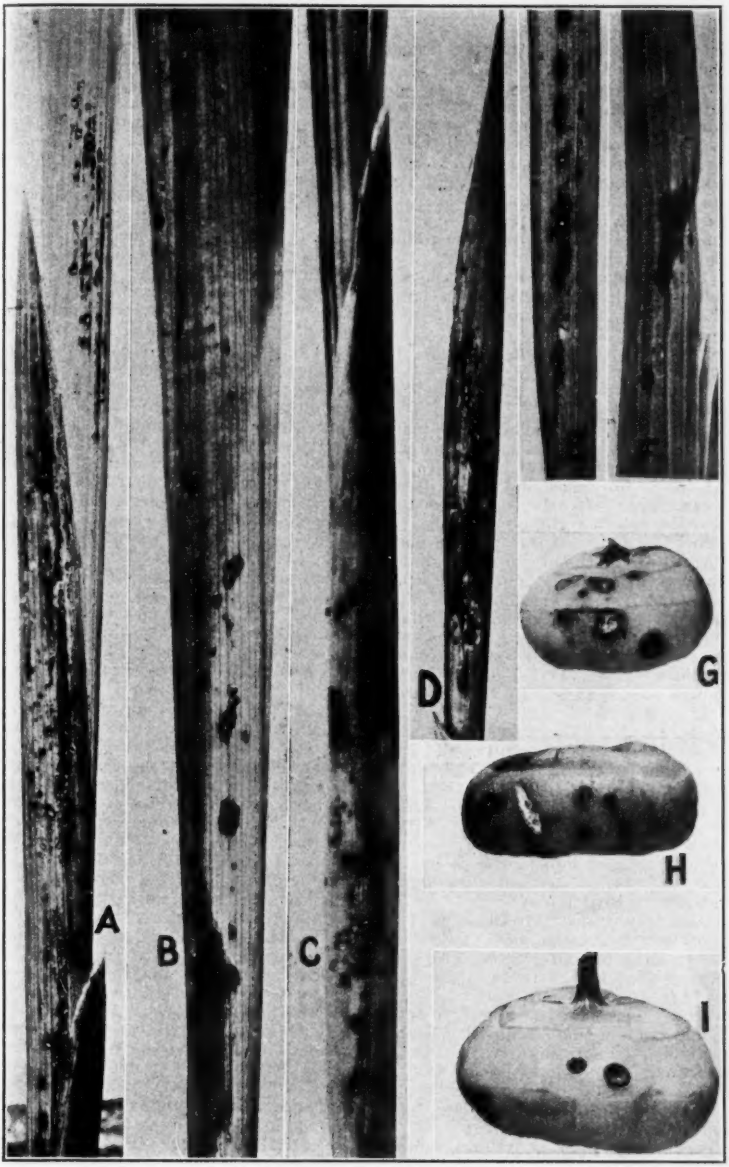
From 3-day-old cultures of peptone-beef bouillon the rods stained with carbol fuchsin measure 0.9 to 1.8 by 0.5 to 0.6μ. Longer rods are found, but these usually show division lines. The bacteria stain well with all the usual stains. Capsules are present on bacteria obtained directly from the host and are also formed in beef media, and in Thaxter's potato agar (Ribbert's capsule stain was used). No spores have been found. The organism is motile by means of 1 to 4 bipolar flagella. The flagella are mostly found at one end only. However, careful search shows occasional rods with flagella at both ends; a single flagellum at one pole and one to two, rarely three flagella at the opposite pole. In the mounts examined the rods having four flagella at one pole have none at the opposite pole (Pl. 5, I). The flagella are 3 to 8μ long. These were stained by Casares-Gil's method. Gram-negative. Not acid fast. Long chains develop in 2 and 3 per cent salt-beef bouillons, short chains in the usual beef media. Involution forms as very slender granular rods were found in beef bouillon cultures grown at 39° C. In potato agar plus dextrose the bacteria are usually large, some as wide as 0.8μ, and rather granular. In 1 to 4 per cent dextrose water cultures the growth s scanty and numerous, myceliumlike forms are produced.

CULTURAL CHARACTERS [5]

AGAR POURED PLATES.—On peptone-beef agar, reaction +10 to +14, colonies appear in 18 to 24 hours and under favorable conditions are often 10 to 12 mm. in diameter at the end of 5 days. Colonies are at first circular, smooth, shining, almost hemispherical, usually amorphous and opaque, sometimes thinner, translucent and with concentric striations. Margins entire. In 1 to 3 days a marginal growth develops, which increases from a thin, narrow, barely visible film (Pl. 5, A) into a well-defined border of considerable width and thickness. Average colonies 4 to 5 days old have centers 2 to 3 mm. in diameter, surrounded by borders 2 to 4 mm. wide. (Pl. 5, B, C and G). Well isolated colonies sometimes produce borders 7 to 8 mm. in width (Pl. 5, D). The border, at first extremely and uniformly thin, becomes thicker and contoured by the development of short, more or less irregular, radiating ridges. In 8 to 14 days the border is about as thick as the central area which remains smooth and does not increase appreciably in diameter (Pl. 5, E). The appearance and development of this outer margin is greatly influenced by the temperature and the degree of isolation. The growth is white, soft, and viscid in consistency. Buried colonies are round to oval, occasionally triangular, outlines smooth, opaque becoming translucent. In thickly sown plates the characteristic marginal growth may be so delicate as to escape casual observation and sometimes it is entirely lacking.

AGAR STABS.—In peptone-beef agar growth is good on the surface, uniformly thick, smooth, white, opaque to translucent. The stab is visible for a

[5] Cultures were grown at room temperature, approximately 25° C., unless otherwise specified.
Beef infusion was used for all the beef media.
Difco peptone and Eimer and Amend agar were used in the media.
For the media used for the optimum reaction for growth three sets of determinations were made. First, it was titrated and the Fuller scale readings obtained, then PH determinations were made colorimetrically, according to the Clark and Lubs' method, and electrometrically.
"Color Standards and Color Nomenclature": Robert Ridgway, used in describing color in cultures (7).



BACTERIUM MARGINATUM ON GLADIOLI PLATE 4

Leaves and corms inoculated with pure cultures of *Bact. marginatum*. All natural size.
A.—Inoculated with bacteria from gummy exudate. Photo 20 days after inoculation.
B to E.—Inoculated with bacteria from corm lesions. B, 10 days, C, 9 days after inoculation.
F.—Lesions on upper part of leaf, 11 days after inoculation.
G, H, I.—Healthy, growing corms inoculated in May by adding bacteria to the soil. Dug a month later and pure cultures of *Bact. marginatum* isolated from pits on each corm.

few days as a finely granular streak, then disappears.

AGAR SLANTS.—On peptone-beef agar growth is smooth to slightly pitted. Margins definite, entire. Transparent to translucent. White, very viscid. On 2 per cent agar the growth is somewhat restricted. On 1 per cent agar the growth quickly spreads over the surface and forms a pellicle over the water in the V and a white, fine grained sediment is deposited.

On beef agar there is often a lack of uniformity in the interior structure of the growth, some areas being quite translucent, others opaque. This gives a mottled appearance to the growth.

BEEF BOUILLON.—In peptone-beef bouillon+14 at 24° C. there is thin clouding and a thin pellicle in 18 hours. Clouding is best at the surface and never becomes heavy. Pellicles are white, membranous, and viscid, falling when even slightly disturbed and another pellicle forming promptly. As many as five definite pellicles have formed in one culture tube. Sediment consists of a scanty amount of white substance, small crystals, and fallen pellicles. Pellicles eventually disintegrate and form a viscid, translucent mass. The medium also becomes viscid.

GELATIN PLATES.—In +10 peptone-beef gelatin at 18° to 20° C. the colonies grow slowly. They have the same character in regard to center and border as colonies in agar plates. The borders remain thin and narrow and are slightly lobed at the margin. Liquefaction was noted first after 5 to 7 days as a narrow rim about the colony. The margin of liquefaction is smooth and definite. Eventually the colony floats in a clear liquid.

GELATIN STABS.—At 18° to 20° C. in +10 gelatin liquefaction becomes visible in 48 hours and proceeds at a moderate rate. In 5 to 6 days the liquefied layer is 5 to 7 mm. deep. There is a thin, white pellicle, thinly clouded liquid and a small amount of white sediment. Four to six weeks are required for complete liquefaction of tubes containing 10 cc. of gelatin.

BLOOD SERUM.—On Loeffler's blood serum at room temperature (25° to 27° C.) growth is abundant, smooth, white, opaque. The medium becomes translucent, light amber in color, and the consistency of soft jelly.

POTATO CYLINDERS.—Growth on steamed potato is scanty. A very thin, white growth over the potato and slight white deposits along margins where the potato touches the tube are the only indications of growth. The water remains clear, sometimes slightly browned. The potato discolors slightly. The diastasic action is feeble.

POTATO AGAR.—Potato broth with agar. Growth on this medium is limited. Thin, white, becoming dull white. No change in the color of the medium.

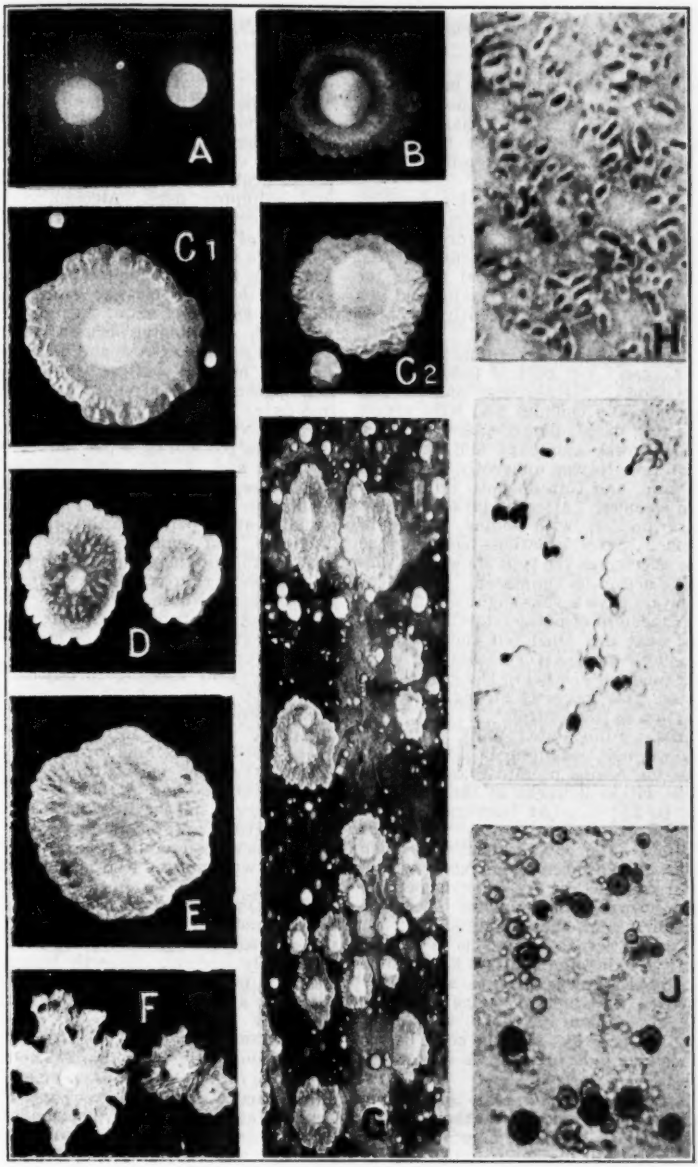
POTATO AGAR WITH DEXTROSE [6].—Colonies in plates are at first smooth, shiny, hemispherical, like tiny drops of boiled starch. In 2 to 3 days the surface is finely wrinkled or coarsely pitted, and a trace of brown color has appeared. In 5 to 6 days the colonies are rather umbonate and brown at the margins. In 10 to 12 days the whole colony is brown and widely separated colonies have developed a new, thin, cream-colored marginal growth. Colonies in thickly sown plates are less likely to turn brown than well isolated colonies.

On slants and stabs the growth is first white, opaque, and slightly contoured. Later the growth is very abundant and the surface becomes smooth and shining. The color of the growth in most isolations becomes tawny to russet brown, the color usually showing first at points where the growth touches the wall of the tube. On soft, moist agars the growth is often quite smooth from the beginning. The growth is butyrous in consistency. Some isolations produce a dark-brown growth, others become only slightly brown. Microscopic examination of the brown growth shows the color to be due partly to brown bacteria which vary in size from small coccilike forms to abnormally large rods; and partly to brown, spherical bodies (Pl. 5, J) the character of which is yet to be determined. They may be degenerate bacteria, or a substance formed by bacterial action.

The brown bacteria and the brown spheres occur together in pseudozoogloeal masses, the surrounding growth consisting of normal, hyaline bacteria.

There is also produced a definite change in the medium as evidenced by an area of increased translucency bordering the brown growth. This forms a halo about plate colonies, rapidly spreading out until all the agar in the plate is changed. In stab and slant tube cultures a deep layer

[6] A modified Thaxter's potato agar. Potato 500 grams, sliced and steamed, in 1,000 cc. of distilled water, strained, 1½ per cent agar added, steamed again, filtered, 2 per cent dextrose added, tubed, and sterilized.



BACTERIUM MARGINATUM ON GLADIOLI PLATE 5

A.—Colonies on beef agar, 2 days old. ×3
B.—Colony on beef agar, 3 days old. ×3.
C.—Colonies on beef agar, 5 days old. ×3
D.—Colonies on beef agar, 6 days old. ×2.
E.—Colony on beef agar, 7 days old. ×3.
F.—Colonies 3 days old. Plated from beef bouillon that clouded at 40° C. ×4
G.—Colonies 5 days old. Oblique lighting to show elevation. ×1¾.
H.—Capsules, 2-day beef agar culture. Ribbert's Dahlia stain. ×2000.
I.—Flagella. Casares-Gil stain. ×1,500.
J.—Brown spheres formed in potato agar plus 2 per cent dextrose. ×500.

below the growth becomes more translucent. Tests show that the sugar has disappeared from this changed part of the medium but that the starch content is practically the same as in the controls.

A very characteristic odor develops in cultures on this medium. It suggests ammonia, also hydrogen sulphide, sauerkraut and fermenting fruits. Cultures kept on artificial media for long periods produce less odor and less brown color than recently isolated cultures.

STARCH AGAR.—To ordinary peptone-beef agar 1 per cent of potato starch was added. Streaks were made on this medium and colonies also were grown by the usual poured-plate method. Growth was abundant and the marginal growth was unusually wide, 5 to 20 mm., and thin on both the streaks and colonies. After 10 days the plates were flooded with iodine potassium iodide. Seven isolations including the one selected as the type showed no diastasic action on the starch. One other isolation gave a very slight reaction.

A medium of potato starch, dextrose and agar was tried but the organism produced on this very scanty growth. The medium just below the growth was tested and gave as strong a starch reaction as the control.

MILK.—Inoculated milk forms a smooth, soft coagulum in 3 to 4 days. Clearing begins promptly and is complete within 2 weeks at temperatures 30° to 33° C. (At temperatures 26° to 29° the digestion is somewhat slower.) The medium becomes pale yellow, translucent and very viscid. After some weeks the color deepens to light brown or deep cream. Reaction is at first acid, then alkaline.

LITMUS MILK.—There is a slight, fugitive reddening which is likely to be overlooked unless cultures are closely watched. Reduction begins promptly and is complete in from 6 to 8 days. In 2 weeks or less the blue color begins to return and in 4 or 5 weeks the cultures are dark blue.

Some puzzling crystals formed in milk cultures. In general they may be described as brittle, hollow spheres 1 to 1.5 mm. in diameter; fairly smooth on the surface but not shining. A few were found hanging from the pellicle-like surface growth but most were on the surface of the sediment. Under microscopic examination the wall appears to be composed of minute crystals and some amorphous substance. They resist considerable pressure. If cut, the edges are fairly smooth. The interior cavity has a diameter about one-half that of the whole sphere. Water does not dissolve these crystals, neither does 10 per cent KOH so it would seem that they are not composed of sugar or casein. They dissolve in acetic acid, dilute hydrocholoric acid, and sulphuric acid. Alcohol, xylol, ether, acetone, chloroform, and ammonia had no effect.

LITMUS AGARS WITH SUGAR.—Litmus agar with 1 per cent peptone and 1 per cent of dextrose, lactose, saccharose, maltose, galactose, mannit, or glycerin was used. Reddening occurred within 24 hours in the dextrose and galactose. Lactose, mannit, maltose, saccharose, and glycerin showed slight reddening in 3 days.

FERMENTATION TUBES.—Fermentation tubes containing 2 per cent Difco peptone and 2 per cent dextrose, saccharose, lactose, galactose, maltose, mannit, or glycerin produced abundant clouding and a pellicle in the open end. Dextrose and galactose gave most growth and in these there occurred a faint clouding after 12 days in the closed ends. No gas formed.

Fermentation tubes containing sterile milk produced no gas. The milk cleared rapidly in the open end, followed by slow clearing in the closed end. The reaction of the cleared milk was alkaline.

Nitrate bouillon in fermentation tubes clouded well and formed a pellicle in the open end within 2 days, and a faint clouding in the closed end was observed on the fifth day in one set of cultures and on the tenth day in another set. Ammonia was produced. Nitrates were not reduced. No gas was produced.

TOLERATION OF SODIUM CHLORIDE.—In peptone-beef bouillon containing 2 per cent sodium chloride, the growth is practically normal. Growth becomes less in 3 per cent, very scanty in 3½ per cent, and in 4 per cent no growth occurred.

USCHINSKY'S SOLUTION.—Thin uniform clouding occurs in 24 hours. A pellicle forms. There is no color reaction except a trace of green in some cultures after 8 weeks. The medium becomes as viscid as egg albumen and with age and evaporation it is almost like rubber.

FERMI'S SOLUTION.—Growth is better in Fermi's solution than in Uschinsky's. Thin, membranous pellicles form repeatedly. As many as nine pellicles have formed in one culture tube. After 3 to 4 weeks the medium is pale yellowish green. Not viscid.

COHN'S SOLUTION.—Growth is slow at first but after a few days is about

equal to that in Uschinsky's solution or beef bouillon. Numerous crystals form in the pellicle, in fact the weight of the crystals causes the pellicle to fall. Fallen pellicles and crystals form the sediment. The pellicles and sediment are slimy to viscid. In most tests the sediment becomes yellowish. One set of cultures developed a pale but clear orange-yellow color in the pellicles, crystals, and sediment.

NITRATE BOUILLON.—There is good growth in this medium, but nitrates are not reduced.

INDOL.—In Dunham's solution, in 1 per cent and in 2 per cent peptone water a slight amount of indol was produced.

AMMONIA.—Tests were positive for ammonia in cultures grown in 2 per cent peptone water, milk, beef bouillon, and other media.

HYDROGEN SULPHIDE.—Produced only in very slight amounts.

AEROBISM.—Shake cultures of agar show growth only at the surface. No growth occurs at the lower end of stab cultures in agar or gelatin. Plate and tube cultures made no growth in an atmosphere deprived of oxygen.

OPTIMUM REACTION FOR GROWTH IN BOUILLON.—The organism grows best in peptone-beef bouillon titrating +8 to +12. Sodium hydrate was used as the alkali and hydrochloric as the acid. It grew well in various acid reactions up to +40. Growth occurred in +43 in 48 hours and in +45 within 6 days in one case and within 10 days in another. No growth developed in medium more acid than +45. The range of growth was more limited on the alkaline side. The amount of growth gradually lessened from +10. In −4 to −5 clouding was evident within 24 hours. In −6, −7, and −8 clouding was not observed until the second day. In −9, no growth. In several cases clouding was observed on the fifth day in −9, but here it was assumed that the medium had become more acid in the interval.

In addition to the titration by Fuller's method with phenolphthalein used as the indicator, colorimetric determinations (Clark and Lubs' series) were usually made and in some cases determinations by the electrometric method (Table I).

In bouillon made with beef extract and titrating +30 the organism made no growth. With this mediun titrating from +3 to +25 the organism grew within 24 hours.

TOLERATION OF ORGANIC ACIDS.—Peptone-beef bouillon +12 containing malic, citric, oxalic, and tartaric acids in amounts to make 0.1, 0.2, and 0.3 per cents were inoculated from 3-day-old beef bouillon cultures. The organism grew well in the 0.1 and 0.2 per cent of malic, citric, and tartaric acids. In 0.1 per cent oxalic acid growth occurred only as a surface pellicle. No growth occurred in 0.2 per cent oxalic, or in any of the 0.3 per cents acids.

TABLE I.—*Reactions of Bacterium marginatum to acid and to alkali in beef bouillon (+ indicates growth; −, no growth)*

Fuller	Colorimetric	Electrometric	24 hours	48 hours	5 days
	P_H	P_H			
−9	9.2	8.96	−	−	−
−9	9.1	8.63	−	−	+
−8	8.8		−	+	+ very faint
−7	8.8	8.5	−	+	+
−6.5	9.0	8.59	−	+	+ faint
−5	8.7		+ very faint		+ faint
−4	8.6		+ faint		+
−2	8.3		+ faint		+
0	8.2		+ faint		++
+5	7.9	7.7	+	++	+++ abundant
+8	7.2		++ moderate	++	+++ abundant
+10	7.1		++ moderate	++	+++ abundant
+12	7.0	6.89	++ moderate	++	+++ abundant
+15	6.7		+		++
+20	6.6	6.55	+		++
+25	6.4	6.26	+ faint		++
+33	5.3		± faint		++
+35	5.2	4.87	+ faint		++
+39	4.8	4.6	+ very faint		++
+39			−	+	++
+41			−	+	++
+43			−	+	++
+44(?)	4.6	4.62	−	+	+
+45(?)	4.6	4.58	−	−	−
−46(?)	4.6	4.61	−	−	−

Titration of these media showed that the 0.1 per cent acid media ranged from +20 to +26, the 0.2 per cent from +42 to +43, and the 0.3 per cent from +63 to +78.

TEMPERATURE RELATIONS.—In peptone-beef bouillon the optimum temperature for growth is about 32° C. Clouding occurs more promptly at 34° to 35° than at 30° to 32°, but after 24 hours growth is better at the lower temperature.

The minimum temperature for growth is at 8° to 9° C. The organism remained alive for 4 months, and probably longer, at 1° to 2°. The maximum temperature is 40°. Various trials indicate a thermal death point at 52° to 53°. Occasional cultures have given growth after a 10-minute exposure to 54°.

FREEZING.—The freezing for 1 hour of 24-hour-old beef bouillon cultures reduced the number of bacteria 40 to 50 per cent.

DESICCATION.—Drops of beef bouillon cultures 18 to 48 hours old were transferred to sterile cover glasses and dried in sterile Petri dishes. The results indicate that the younger cultures are less resistant than older. This may be due to the fact that the older cultures are already somewhat viscid, do not spread so well, and probably retain moisture longer than the young cultures. Young cultures resisted drying from 4 to 5 days. Older cultures gave growth up to 14 days.

EFFECT OF SUNLIGHT.—Beef-peptone agar plates, thinly sown, were exposed on ice to sunlight in July at 11 a. m. Ten minutes' exposure killed 50 to 70 per cent and 20 minutes' exposure killed practically all the bacteria.

VITALITY.—At Washington room temperatures the bacteria in culture media die in 7 to 9 months. This may be due partly to drying of the media. At lower temperatures (14–18° C.) cultures live more than a year but the pathogenicity is reduced by age. Some young cultures were mixed with sterile soil which was then placed at 1–2° for 4 months, then at 8–9° for 3 weeks. From a bit of this soil the bacteria were isolated in great numbers. These tubes then remained in a closet at room temperature and the bacteria were alive and virulent 11 months after being put in the tubes. After 15 months isolations showed the bacteria still very much alive but no pathogenic test was made. No growth was secured from lesions on leaves kept at room temperature for 7 months.

VARIATIONS.—Cultural studies and infection experiments have proved that the various isolations are similar in their essential characteristics, though not absolutely alike. One isolation from plants grown in Virginia liquefies gelatin more rapidly than the one selected as the type. Another from Michigan produces more abundant growth on artificial media. Some isolations are less viscid than others and occasional sets of beef bouillon cultures never become viscid. The bacteria isolated in 1913 browned beef media. Later isolations have not discolored beef media but some of them have slightly browned potato agar plus dextrose. The brown growth on potato agar plus dextrose occurs in most but not all of the isolations.

GROUP NUMBERS.—The group number, according to the descriptive chart (1907) of the Society of American Bacteriologists, is 211.2222022. According to the 1920 chart it is 5322–31130–1222.

TECHNICAL DESCRIPTION

Bacterium marginatum, n. sp.

Cylindrical rods rounded at ends, occurring singly and in pairs; 0.8 to 1.8 by 0.5 to 0.6μ; aerobic; motile by means of one to four bipolar flagella; no spores; capsules present; stains readily but often shows granular structure; Gram-negative; not acid fast.

On beef agar the colonies are white, circular, becoming more or less irregularly lobed; center smooth, almost hemispherical, surrounded by a wide border which is thin at first becoming thick and contoured.

Liquefies gelatin and softens blood serum; produces slight amount of acid in milk, then becomes alkaline; digests casein; produces acid in cultures with various sugars, especially in galactose and dextrose. Nitrates are not reduced. No gas is produced. Slight amounts of indol, hydrogen sulphide, and ammonia are produced. Grows well in Uschinsky's, Fermi's, and in Cohn's solutions. Viscid in most media. Not viscid in Fermi. Temperature for growth, maximum 40° C., minimum 8° to 9°, optimum 30 to 32°. Thermal death point about 53°. Remains alive at temperatures below 9° for 4 months or more; not particularly sensitive to drying; freezing for 1 hour killed 40 to 50 per cent; sunlight for 10 minutes killed 50 to 70 per cent.

Pathogenic on gladiolus leaves and corms, producing reddish brown lesions, circular to elongated on the leaves, and circular, shallow brown pits on the corms.

Specimens of the disease on leaves and corms have been deposited in the

herbarium of the Bureau of Plant Industry, United States Department of Agriculture.

SUSCEPTIBILITY

This disease has been observed on practically all the varieties of the gladiolus commonly grown by florists but most of the inoculation tests and close observations have been on the varieties America and Mrs. Francis King.

OVERWINTERING AND DISSEMINATION

It has been demonstrated that the organism may be carried over from season to season on the corms. The causal organism has been found in a living and virulent condition on corms, stored under usual conditions, 9 months after being harvested. Corms as badly marred as those shown in Plate 3, with the husks so disintegrated that the pitted body of the corm is exposed, would probably be discarded by most growers. Other corms having small, inconspicuous spots on the outer husks might pass as healthy. These spots may or may not extend through the several layers of husks to the corm.

Infected husks are probably as great, if not a greater, source of infection than infected corms, for the reason that at planting time or later in cultivating, broken or loose pieces becoming incorporated with the soil, may come in direct contact with the plants.

Great numbers of the parasite are often found on the husk parts through which the growing bud must push and some of the infecting material, carried along with the growing leaves, may eventually succeed in producing leaf infections which become foci for other infections. Meanwhile on the parent corm the husks are disintegrating and the body of the corm is changing to a shrunken mass on which the old pits are still distinguishable but not increased in size or depth.

Observation of many plants indicates that the new corm, though in such intimate contact, is not ordinarily directly infected by the diseased parent corm. Many healthy plants have been grown in the greenhouse from diseased corms. The husks were removed and the corms planted rather deeply in clean sandy soil. These plants were not repotted nor was the soil disturbed in any way. In practically every case healthy plants and clean, new corms were produced. Similar corms planted outdoors in a bed where the disease had occurred for several years and cultivated in the usual way, invariably became infected. It was observed that the loose soil was dashed on the plants by every rainstorm and considerable soil left sticking to the lower leaf parts and that infection occurred most abundantly on the parts spattered with soil. This, as well as some other experiments, indicates that the infection came from infected soil.

Inoculation experiments have shown that the corms are most easily infected when the husks are young and still full of moisture. Unless the bacteria come in contact with the husks during this susceptible period the parasite seems unable to penetrate deeply enough to reach the body of the corm.

Favorable temperature and moisture of the soil are also doubtless factors in the initial infection and in the continued activity of the bacteria. It has been noted that plants in the moister parts of fields and beds have heavier infection than surrounding plants in better drained soil.

The part played by insect transmission of the disease also needs to be considered. In a few cases of corms planted in unsterilized garden soil, mites have been found in connection with the lesions of the husks and corms. The mites had made perforations in the dark husk spots and small burrows in the corm spots. Except for the holes these lesions were typical for *Bacterium marginatum* and this organism was isolated from both husk and corm spots that definitely showed mite attacks. If mites are able to penetrate normal gladiolus tissues, they probably aid in distributing the infection.

DISINFECTION EXPERIMENTS

Disinfection experiments have not been extensive but it is believed that corms can be treated so as practically to control the disease.

The following experiment was made, using badly pitted corms, variety Mrs. Francis King:

The corms were first soaked for 15 minutes in water, then the water was poured off and the corms were protected so as to retain moisture for several hours. This process softened the hardened exudate, which otherwise might have interfered with the action of the disinfectant. Four lots were then treated for one-half hour as follows—

(*a*) Mercuric chloride, 1–1000.
(*b*) Copper sulphate, 1 ounce to 1 gallon of water.
(*c*) Formalin, 1–40.
(*d*) Formalin, 1–80.

After this one-half hour treatment the solutions were poured off and part of the corms planted at once in sterile soil. The others were allowed to dry.

When the corms had dried, lesions were taken from all the lots and isolation plates made without any further sterilization, but each lesion was washed through three changes of sterile water to remove any disinfectant that might be on the surface.

Bacterium marginatum was secured from husks of the corms treated with mercuric chloride, but considering the heavy inoculation of the plates, there were not many viable bacteria in these husks. No *Bacterium marginatum* was obtained from the husks of the other three lots or from corm spots of any of the four. A small number of bacteria and fungi of several sorts appeared in the plates. In general, there was a striking reduction in the number of organisms.

Three weeks after treatment the rest of the corms were planted in pots of sterile soil. All the corms produced healthy, vigorous plants. Six months later when they were dug the new corms and cormlets were free from spots, except a few in the lot treated with copper sulphate, which had slight but definite husk lesions.

In another experiment typically pitted corms of the varieties Mrs. Frank Pendleton, Mrs. Francis King, Schwaben, America, and a few of unknown variety, were treated for 1½ hours in formalin 1–60, then planted while still damp in clean soil in pots. There were 80 corms in this lot and the husks were not removed. All grew well and produced vigorous plants. Four and a half months later a few were blooming and in most the new corm was fairly well developed. No sign of infection was found on leaf parts or on corms.

Sixty healthy corms were treated the same as the pitted corms. Fifty were planted in sterile soil and ten in soil taken from a bed where the bacterial disease had occurred the previous season. Those in sterile soil produced clean plants and corms. Those in the infected garden soil had no infection on the parts above ground, but the "neck" and new corm of all showed typical spots after 5 months' growth and isolation plates produced typical colonies of *Bacterium marginatum*. Special effort was made to keep the soil surface firm and there was practically no soiling of the lower leaves.

OTHER HOSTS

On iris a very weak infection occurred if the inoculated areas were kept moist for several days. The spots caused by the bacteria were reddish-brown surrounded by a water-soaked area.

Calla lily leaves and petioles were inoculated but never showed any infection.

OTHER BACTERIAL DISEASES OF THE GLADIOLUS

In 1913 G. Severini (*10*) published descriptions of two bacterial diseases of gladioli. Both are soft rots attacking chiefly the underground parts of the plants. Neither of these organisms, *Bacillus ixiae* G. S., and *Pseudomonas gladioli* G. S., in morphological or in cultural characters is like the organism, *Bacterium marginatum*, described in this paper.

Prillieux and Delacroix (*6 p. 670*) have published a very brief note concerning deeply corroded brown spots on the roots of "Glaieul". A short, very motile bacillus was found in the tissues. In bouillon cultures no color change took place in the medium. No name was given the organism and no further description has been found concerning this bacillus.

Rostrup (*8, p. 473; 9, p. 175*) refers to a disease of hyacinth and gladiolus which causes yellow stripes on the leaves in which bacteria have been found.

A yellow bacterium causing translucent spots on gladiolus leaves was described in 1924 by McCulloch (*3*). The appearance of the lesions and the characteristics of the causal organism are quite unlike *Bacterium marginatum*.

Mizusawa (*5*) reports a disease on crocus due to *Bacillus Croci* Mizusawa, and his photographs of colonies resemble *Bacterium marginatum* but the cultural characters and morphology of the bacteria are unlike *Bact. marginatum*.

Wallace (*11*) refers briefly to a disease of gladiolus, "a soft rot probably caused by bacteria." No description is given of the disease or the organism.

SUMMARY

The bacterial disease of gladiolus described in this paper has been under observation for several years in the

District of Columbia and near-by localities. This disease has been found on gladioli grown in Michigan, Ohio, Pennsylvania, Maryland, Virginia, Florida, California, and Indiana.

The leaf injuries vary from minute, reddish spots to large, brownish areas occurring most abundantly on the lower part of the leaves. The parenchyma is first destroyed and later the vessels become unable to supply sufficient moisture to the leaf which becomes brown and dry.

Infected corms are more or less disfigured by circular, shallow depressions. These are usually brown in color, horny or brittle in texture, and exude a gummy substance. The spots on the husks are brown to black, eventually disintegrating and exposing the body of the corm.

Isolations have been made from lesions on leaves, husks, corms, and from the exudate, and the pathogenicity of the bacteria from all these parts proved by inoculation experiments.

Living, virulent bacteria have been isolated from corm lesions 9 months after being harvested.

The organism causing these lesions is a medium-sized rod, having a capsule and one to several polar flagella. On beef media it forms a white, viscid growth.

This organism grows best at temperatures between 25° and 30° C. (77–86° F.). Moisture, heat, and succulent tissues favor the progress of the disease.

There is evidence that this organism remains alive in the soil in which diseased plants have grown. Crop rotation should be practiced.

Control experiments have not yet been extensive enought to indicate the best methods for prevention, but considerable success has resulted from treating the corms with either mercuric chloride (1–1,000) or formalin (1–80).

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NEW TERMITES AND HITHERTO UNKNOWN CASTES FROM THE CANAL ZONE, PANAMA[1]

By THOS. E. SNYDER

Entomologist, Forest Insect Investigations, Bureau of Entomology, United States Department of Agriculture

INTRODUCTION

The agricultural development of the Canal Zone and the clearing of the dense growth of tropical jungle for banana, pineapple, avocado, and cacao plantations will result in the killing of many termite colonies of species that require a moist habitat. The intense heat of the tropical sun will render the decaying logs, stumps, and branches on the ground and even the soil too dry and unsuitable for them. Large areas of the Zone already have been cleared of termites by the formation of Gatun Lake, which flooded the land, thereby drowning the termite colonies in the soil. Nevertheless, termites will always constitute a serious problem in Panama, and damage to the woodwork and contents of buildings as well as to living vegetation must be carefully guarded against.

The writer spent the month of February, 1924, in the Canal Zone and adjacent portions of the Republic of Panama, where several new and striking termites were collected by Messrs. J. Zetek, I. Molino, and himself. During his visit a new subgenus, Uniformitermes, of the genus Nasutitermes Banks was found, which contains two types of soldiers of similar form or shape. Species were found in two rare American genera, namely, Cylindrotermes Holmgren from Bolivia (species, *nordenskiöldi* Holmgren) and Rhynchotermes Holmgren (a subgenus of Armitermes Wasmann, from South America), hitherto monotypic (species, *perarmatus* Snyder); neither genus had been found previously in Panama.

The three species in the genus Cryptotermes Banks found in Panama in the latter part of the nineteenth century by Dudley and Beaumont, who gave no definite locality records, were rediscovered, and the hitherto unknown deälated adult of *Cryptotermes longicollis* Banks was found (fig. 2), which will be described after more material has been obtained. A study of *C. brevicollis* Banks (fig. 1) and *C. longicollis* Banks convinced the writer that they should be included in Holmgren's subgenus Lobitermes. *C. dudleyi*, on the other hand, is a Cryptotermes and suppresses *thompsonae* Snyder. Neither Banks's figures nor his description of *C. dudleyi* indicates that the soldier has the anterior margin of the pronotum serrate, the distinctive character of *C. thompsonae*, but the writer has since examined Banks's type.

FIG. 1.—*Kalotermes (Lobitermes) brevicollis:* Mandibles of soldier, showing marginal teeth. (From drawing made by camera lucida)

Interesting biological notes were obtained on the habits of Cylindrotermes and Rhynchotermes; Cylindrotermes (Pl. 1, B) lives under very similar conditions to species of Amitermes (*beaumonti*) and Leucotermes.

The termite fauna of Barro Colorado Island in Gatun Lake, Canal Zone, the

FIG. 2.—*Kalotermes (Lobitermes) longicollis:* Mandibles of soldier, showing marginal teeth. (From drawing made by camera lucida)

site of the new tropical research station, was especially rich and interesting; 20 species, representing 15 genera or subgenera, occurring. At present only 36 species of termites, representing 22 genera or subgenera, have been found in Panama but it is believed that many more species occur. The outlying regions of the Republic of Panama have not been explored for termites and doubtless South American species will be found there. To the writer,

[1] Received for publication June 25, 1924—issued January, 1925.

Central America is an extremely interesting field for biological and taxonomic studies of termites.

Damage by termites to the woodwork of buildings in the Canal Zone is common and severe, while injury to living shade and fruit trees and other vegetation is serious, healthy living trees being attacked and killed. The Bureau of Entomology has therefore begun a series of experiments in the Canal Zone with wood preservative treatments to prevent termite damage to buildings, as well as tests of insecticides to kill Coptotermes infesting trees. J. Zetek, of this bureau, stationed at Ancon, Canal Zone, and the writer are cooperating in this work, some of which, through the courtesy of the Institute for Research in Tropical America, will be conducted at the site of their station on Barro Colorado Island.

The seven new species are *Kalotermes panamae*, *K.* (*Glyptotermes*) *angustus*, *K.* (*G.*) *barbouri*, and *K.* (*G.*) *emarginicollis*, in the family Kalotermitidae, and *Armitermes* (*Armitermes*) *chagresi*, *A.* (*Rhynchotermes*) *perarmatus*, and *Nasutitermes* (*Uniformitermes*) *barro-coloradensis*, in the family Termitidae.

A list of the known termites of the Canal Zone and adjacent Panama is appended. The present paper will be followed shortly by a longer biological paper discussing these termites, their distribution, economic importance, and control.

HABITS AND HABITATS

Unlike ants, termites [2] are not dominant insects. They seldom come above ground to forage in the direct sunlight, and species which do forage above ground are specially modified. The deeply pigmented, sexual adults possess eyes and are phototropic at the time of the annual colonizing flight, known as the "swarm"; but after the flight, which is generally of short duration, the deälated adults rapidly become thigmotropic and seek shelter in or under decaying wood on the ground or in crevices in dead trees. Most termites are blind and live hidden within wood, underground, or in carton tree nests or mound nests on the ground.

Colonies occur under a great variety of habitats—in the sands near sea coasts, in forests, swamps, plains, arid deserts, fields, orchards, and cities. By the clearing of forest land in temperate regions, subterranean termites are often driven to attack the crops and buildings of man. In the moist tropical jungle, subterranean termites inhabiting wood on the ground are often killed by the intense heat of the sun in clearings for crops.

As a rule termites of subterranean habit must come above or near the surface of the ground to procure their food, which consists of wood, vegetation, or roots. To solve this difficulty, these soft-bodied, blind insects take the ground and moisture out with them. Even when working in the tops of lofty trees they are thus "below ground."

For protection and moisture they construct earthlike carton shelter tubes of excreted wood and soil cemented together. Occasionally these run along the ground, but more often mount in extensive ramifications to the tops of the trees, meandering along every branch and twig, and here and there debouching into large covered chambers which occupy half the girth of the trunk. Most trees in some regions are thus fantastically plastered over with tubes, galleries, chambers of earth, and carton nests.

Hence it will be seen that wood, no matter how dry, may be attacked by subterranean termites if there is access to the wood from the soil whence they can obtain moisture.

GEOGRAPHICAL DISTRIBUTION

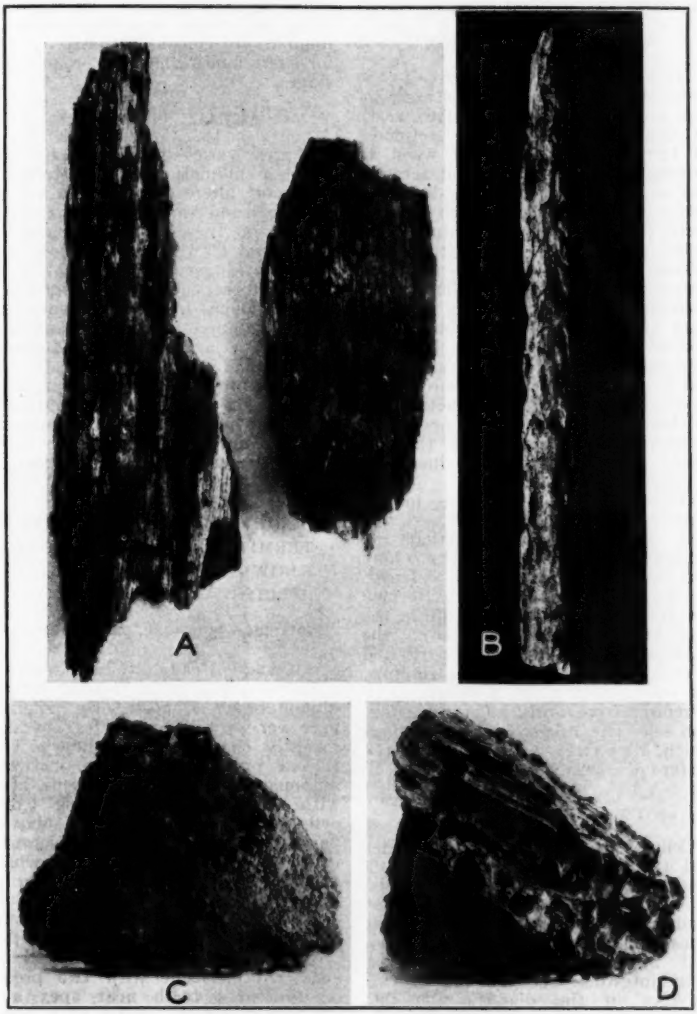
Termites, although widespread, are not to be found in arctic regions or above timber line on mountains. They occur in the temperate regions of the world and in the tropics and subtropics, where termites reach their maximum development. They have not the wide range of distribution of ants, nor are there as many species of termites as there are of ants.

The more permanent nests and more stable colonies occur in the tropics. Colonies in temperate regions have but poorly defined nests and are more mobile; in the tropics specialized nest structures are the rule.

SOCIAL LIFE

Unlike colonies of ants, termite colonies are societies of sexual and sterile castes of both sexes. The male continues to cohabit with the female and copulation is repeated at intervals throughout life. Although soft-bodied and usually blind and sensitive to light, termites are the longest-lived of all insects. Reproductive adults may live

[2] Termites, or "white ants," are termed "comixen" or "comejen" in Cuba and Spanish Central America and South America, but are termed "cupim" in Brazil.



New Termites from the Canal Zone Plate 1

A.—*Armitermes* (*Rhynchotermes*) *perarmatus:* Work in decaying log on ground in jungle.
B.—*Cylindrotermes nordenskiöldi:* Work in branch on ground in jungle.
C, D.—*Mirotermes panamaensis:* Exterior and interior views of nest within dead coconut palm tree on ground where reproductive forms were found, Largo Remo Island, Canal Zone.
Photographs by Zetek and Molino.

for 25 years or more. There is a well-defined division of labor among workers, soldiers, and reproductive forms; all castes are polymorphic.

ECONOMIC IMPORTANCE

Termites are very destructive to the crops, habitations, and other works of man and cause millions of dollars worth of damage. The greatest usefulness of termites is in reducing wood to humus and turning over and aerating the soil. They hasten the decomposition of organic matter such as dead trees, decaying logs, and stumps, thus enriching the soil. In the tropics of Africa and India termites plow and harrow the soil in their burrowings underground, and vegetation taken as food by termites passes through their bodies to enrich the soil. By their subterranean excavations, also, the soil is kept in the constant circulation so conducive to proper productiveness. Without the angleworms or earthworms, ants, and termites, the soil might become barren and incapable of supporting human life.

Although the motivations in the termite colony life are hunger, sex, and fear, there are evidences that the workers regulate the life of the colony and are the "spirit of the colony," as Maeterlinck has so aptly termed the guiding force of colony life in the bee. Some of the actions of the workers, however, can not be attributed to these impulses alone, as, for example, the seasonal slaughter of certain types of reproductive forms. There is a definite selective process in these killings which apparently works out for the welfare of colony life.

FOOD

Cellulose is the chief food of termites and this is obtained not only from living vegetation (living trees, roots, etc.) but also from dead vegetation as dead trees, plants, paper, etc. Recent investigations by Cleveland have shown that most termites have protozoa in the intestinal tract and these act as enzymes in the digestion of this cellulose. Most termites of the family Termitidae, however, do not have protozoa in the intestinal tract although their food is in general similar to that of other termites.

INSECT ENEMIES

Ants are the greatest insect enemies of termites and yet certain species of ants are pacific toward termites and live in their nests, although in separate galleries. No internal insect parasites of termites have been found and possibly this is due to the fact that termites have no resting stage (as immobile larvæ or pupæ) and the young or nymphs are constantly active, except for short molting periods or quiescent stages.

ANIMAL PREDATORS

A great variety of odd and specially adapted animals prey on termites. The most interesting of these are the anteaters, and America contains several species of these peculiar mammals, the largest of which is *Myrmecophaga tridactyla* Linnaeus. Dr. W. M. Mann found another species, *Cyclopes didactylus* Linnaeus, a small, golden-yellow arboreal animal, feeding on termites in Bolivia. A larger species, *Tamandua tetradactyla* Linnaeus (Pl. 2, A, B), also arboreal, preys on termites and often rare species of termites, ants, and inquilines are found in the stomachs of these anteaters if they are killed before the stomach contents are digested.

DESCRIPTIONS OF NEW SPECIES OF TERMITES AND HITHERTO UNKNOWN CASTES OF KNOWN SPECIES

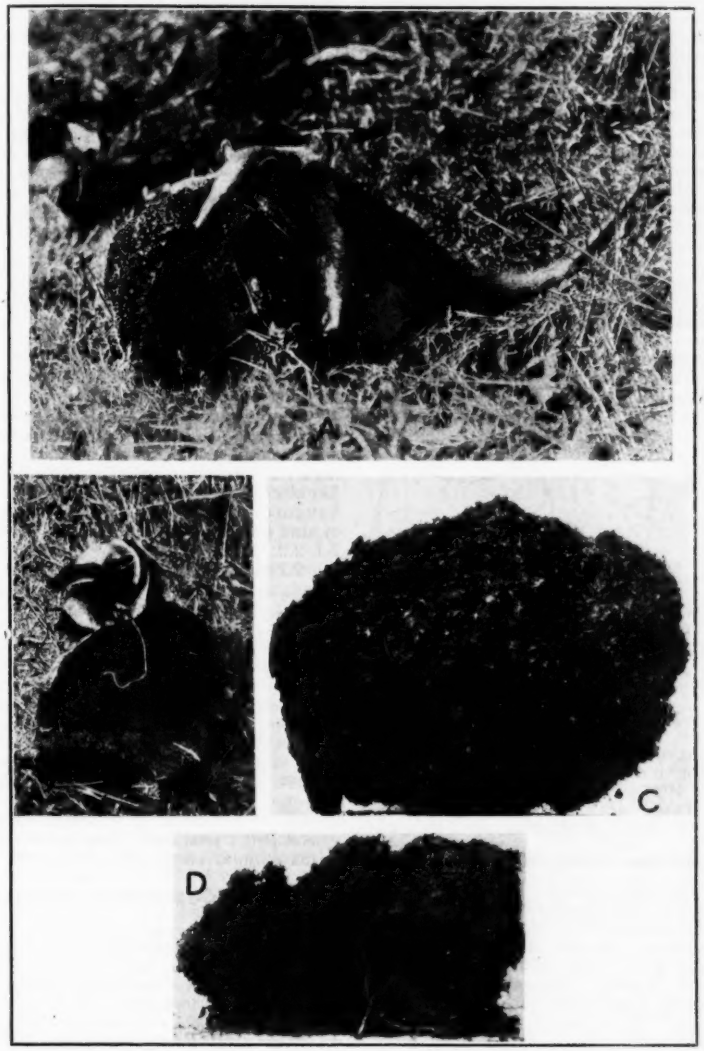
Kalotermes panamae, new species.

SOLDIER.—Head yellowish-brown, darker anteriorly, over twice as long as broad, broadest posteriorly, slightly narrower anteriorly, sides parallel (slightly concave in middle), a chitinized projection or knob between antennal socket and postclypeus, head with very dense fairly long hairs; eye spot hyaline, elongate, suboval, parallel to front of head, epicranial suture on slope of front of head, where there is a slight depression; labrum rounded (broadly) at apex. Gula one-half as wide at middle as at front.

Mandibles blackish, base reddish brown, broad at base, incurved at apex; left mandible with two prominent pointed teeth near apex and three smaller teeth nearer base; right mandible with two prominent teeth near base (fig. 3).

Antennae yellowish, third segment castaneous, of 14 segments, with long hairs; third segment subclavate, approximately as long as fourth and fifth segments together; last segment slender and subelliptical.

Pronotum yellowish, margin darker, as broad as head, broader than long (variable in size), broadly emarginate



New Termites from the Canal Zone Plate 2

A, B.—*Tamandua tetradactyla*, an arboreal American anteater, in whose stomach were found rare termites, feeding on a carton termite nest.

C, D.—*Armitermes* (*Armitermes*) *chagresi:* View of exterior and section of termitarium 20 inches wide, of soft earth on ground near decayed log in jungle, Barro Colorado Island, Canal Zone.

Photographs by Zetek and Molino.

anteriorly, not as deeply as in *K. marginipennis* Latreille, and slightly emarginate posteriorly, anterior margin *not* dentate (fig. 4), sides rounded, with dense, fairly long hairs.

Legs yellowish, tibiae slightly brownish, femora swollen, pubescent.

Abdomen dirty whitish gray, pubescent, with row of long hairs on tergites near base; cerci present but not prominent.

MEASUREMENTS.—Length of entire soldier: 9.50–11.00 mm. Length of head with mandibles: 4.60–4.80 mm. Length of head to anterior margin: 2.90–3.50 mm. Length of left mandible: 1.60–1.70 mm. Length of pronotum: 1.10–1.30 mm. Length of hind tibia: 1.30–1.40 mm. Width of head (where widest): 1.80–2.00 mm. Width of pronotum: 1.80–2.20 mm.

TYPE LOCALITY.—Rio Chinilla, Canal Zone, Panama.

FIG. 3.—*Kalotermes panamae:* Mandibles of soldier, showing marginal teeth. (From drawing made by camera lucida)

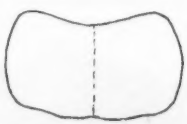


FIG. 4.—*Kalotermes panamae:* Dorsal view of pronotum of soldier, the anterior margin *not* dentate. (From drawing made by camera lucida)

Described from six soldiers, collected with nymphs in a decaying log in jungle, at the type locality, by I. Molino and T. E. Snyder on February 22, 1924.

TYPE, SOLDIER.—Cat. No. 27266, U. S. National Museum.

Neotermes holmgreni Banks.

SOLDIER.—Head light castaneous brown, paler posteriorly, with reddish tinge anteriorly, elongate, sides slightly concave, broader anteriorly, frontal slope with lobed epicranial suture, eye spot hyaline, elongate, parallel to frontal slope, head with scattered long hairs. Gula slender in middle.

Mandibles black, base reddish, broad at base, more slender toward apex; incurved at apex; right mandible with two sharp, pointed teeth near base, slightly crenulate toward apex; left mandible with three "molar" (double) teeth with first teeth more prominent.

Antennae light brown, paler anteriorly, not as long as mandibles, of 13 segments, with long hairs; third segment slightly modified, subclavate, slightly longer and broader than second and much longer and broader than fourth; fifth longer than fourth, segments becoming longer toward apex; last segment slender, shorter and subelliptical.

Pronotum gray-white with pale yellowish tinge, darker (brownish) on margins, anterior margin broadly, roundly but shallowly emarginate (concave), posterior margin convex, sides rounded, anterior corners rounded and somewhat raised, mesonota and metanota with very short wing pads, with scattered fairly long hairs.

Legs white with yellowish tinge, short, femora slightly swollen, pubescent, pulvillus absent.

Abdomen dirty white with yellowish tinge, with scattered shorter hairs and a row of long hairs near base of each tergite, cerci short.

MEASUREMENTS.—Length of entire soldier: 9.5–11.5 mm. Length of head with mandibles: 5.1 mm. Length of head to anterior margin: 3.3 mm. Length of left mandible: 1.8 mm. Length of pronotum: 1.2 mm. Length of hind tibia: 1.2 mm. Width of head: 2.1–2.2 mm. Width of pronotum: 2.1–2.2 mm.

Described from a series of soldiers collected with nymphs at the type locality (Taboga Island, Republic of Panama) by the writer on February 17, 1924, in a decaying branch on the ground. These specimens are in the collection of the United States National Museum. No winged adults were collected with these soldiers. The winged adult was described by Nathan Banks in 1918, and these are the first soldiers collected, this caste being hitherto unknown. Specimens of soldiers from Ancon Hill, Canal Zone, show variations in mandibular teeth, pronotum, etc.

Kalotermes (Glyptotermes) angustus, new species.

WINGED ADULT.—Head shining, dark castaneous brown, lighter below the eyes, longer than broad, sides parallel, with scattered long hairs; eyes black, not round, large, slightly projecting, separated from lateral margin of head by a distance less than half an eye diameter; ocelli hyaline, small suboval, close to and at an oblique angle to eye.

Antennae light brown, of 12 segments, with long hairs; segments becoming longer and broader toward apex; third segment subclavate, longer than fourth but shorter than second; last segment longest, apex appearing to be somewhat obliquely truncated.

Pronotum same color as head, anterior margin broadly, shallowly, roundly emarginate, sides sloping roundly to posterior margin, where slightly emarginate, with few scattered long hairs.

Wings with costal veins brownish, no branches between costal veins, membrane yellowish, coarsely punctate; forewing with median close to and parallel to subcostal vein, cubitus slightly nearer to median than to lower margin (a little above middle of wing), branching to apex of wing, with subbranches to lower margin.

Legs light yellow-brown, pulvillus present, pubescent.

Abdomen with tergites same color as head, a row of long hairs at base of each tergite, cerci present, but not prominent.

MEASUREMENTS.—Length of entire winged adult: 6.00 mm. Length of entire deälated adult: 3.50 mm. Length of head: 1.00 mm. Length of pronotum: 0.50 mm. Length of anterior wing: 4.30 mm. Length of hind tibia: 0.70 mm. Diameter of eye (long diameter): 0.225 mm. Width of head: 0.75 mm. Width of pronotum: 0.70 mm. Width of anterior wing: 1.20 mm.

SOLDIER.—Head light castaneous brown, paler posteriorly, blackish on front, which is nearly vertical, longer than broad, broadest posteriorly, sides approximately parallel, slightly concave at middle, constricted at top of head anteriorly, deeply bilobed medially (narrow V-shaped cut), rims of lobes roughened, tubercular, surface of head smooth, with scattered long hairs. Eye spot hyaline, large, markedly projecting, suboval, and parallel to front margin of head.

Mandibles reddish brown to blackish at apex, short, stout, slender and incurved at apex; left mandible with three marginal teeth, the two near apex approximately parallel to margin of mandible, molar near base; right mandible with sharp-pointed projecting tooth at about middle and molar near base.

Antennae light yellow-brown, of 11 segments, segments wedge-shaped, becoming longer and broader toward apex, with long hairs; third segment ringlike, much shorter than second and slightly shorter than fourth; last segment long and slender, subelliptical and pointed at apex.

Pronotum yellow-brown, darker on margins, narrow, anterior margin broadly, roundly, fairly deeply emarginate, slightly roughened, corners high, sides roundly sloping to posterior margin, where roundly emarginate, with few scattered long hairs (fig. 5, *a*).

Legs whitish with tinge of yellow, femora swollen, pubescent. Abdomen dirty gray-white, with tinge of yellow, tergites with a row of long hairs near bases, cerci not prominent.

MEASUREMENTS.—Length of entire soldier: 4.40–4.80 mm. Length of head with mandibles: 1.80 mm. Length of head to anterior margin: 1.30 mm. Length of left mandible: 0.65 mm. Length of pronotum: 0.45–0.50 mm. Length of hind tibia: 0.70 mm. Width of head posteriorly: 0.95 mm. Width of head anteriorly: 0.90 mm. Width of pronotum: 0.95 mm.

TYPE LOCALITY.—Rio Chinilla, Canal Zone, Panama.

Described from a series of winged adults and soldiers collected at the type locality in a decaying log on February 22, 1924, by T. E. Snyder and I. Molino.

FIG. 5.—Comparative study of dorsal views of pronota of soldiers of (*a*) *Kalotermes* (*Glyptotermes*) *angustus*, (*b*) *K.* (*G.*) *barbouri*, and (*c*) *K.* (*G.*) *emarginicollis*. (All from camera lucida drawings made to same scale)

TYPE, SOLDIER.—Cat. No. 27267, U. S. National Museum; morphotype, winged adult.

Kalotermes (Glyptotermes) barbouri, new species.

DEÄLATED MALE ADULT.—Head shining, dark castaneous brown, lighter below eyes, slightly longer than broad, sides parallel, with fairly dense scattered long hairs; eyes black, large, slightly projecting, suboval, separated from lateral margin of head by a distance less than an eye diameter; ocelli hyaline, small, suboval parallel to and close to eye.

Antennae broken, yellow brown, with long hairs; third segment subclavate, longer than second or fourth segments; fourth shorter than second segment; segments becoming longer and broader toward apex.

Pronotum same color as head, anterior margin shallowly roundly emarginate, sides roundly sloping to posterior margin, which is nearly straight, with scattered long hairs.

Wings with costal area golden brown, membrane whitish with yellowish tinge, coarsely punctate; hind wing

with median vein close to and parallel with the subcostal vein, cubitus in about center of wing, branching to apex of wing, near base branching into a long vein parallel to cubitus, and with subbranches to lower border of wing.

Legs yellow, tibiae yellow-brown, pubescent.

Abdomen with tergites same color as head, a row of long hairs near base of each tergite; cerci present but not prominent.

MEASUREMENT.—Length of entire deälated adult: 3.70 mm. Length of head: 0.90 mm. Length of pronotum: 0.50 mm. Length of hind tibia: 0.70 mm. Length of hind wing: 4.20 mm. Diameter of eye (long diameter): 0.225 mm. Width of head (at eyes): 0.80 mm. Width of pronotum: 0.70 mm. Width of hind wing: 1.15 mm.

SOLDIER.—Head pale yellowish brown, darker anteriorly (castaneous or reddish brown), blackish on front, which is nearly vertical, longer than broad, broadest posteriorly, sides approximately parallel but slightly narrowed anteriorly, especially constricted on top of head, deeply bilobed medially, with rims of lobes roughened or tubercular, surface of head smooth, with few scattered long hairs. Eye spot hyaline, large, projecting, elongate, suboval, parallel to front of head.

Mandibles reddish brown to blackish, short, stout, incurved at apex; left mandible with three marginal molar teeth, tooth near apex with more pointed, projecting base; right mandible with one molar tooth near base, with fairly sharp, projecting base.

Antennae light yellowish brown, of 10 to 11 segments, segments becoming longer and broader toward apex (wedge-shaped), with long hairs; if 10 segments, third segment longer than fourth but shorter than second; if 11 segments (third dividing), third segment ringlike, shorter than second or fourth; last segment narrow, elongate and subelliptical, pointed at apex.

Pronotum light yellow-brown, darker on margins, anterior margin deeply roundly emarginate, corners high, sides roundly sloping to posterior margin, where nearly straight (slightly emarginate), with few scattered long hairs (fig. 5, *b*).

Legs whitish with tinge of yellow, femora slightly swollen, pubescent.

Abdomen dirty white with tinge of yellow, tergites with a row of long hairs near base, cerci present but not prominent.

MEASUREMENTS.—Length of entire soldier: 4.10–4.20 mm. Length of head with mandibles: 1.60–1.75 mm. Length of head to anterior margin: 1.20–1.30 mm. Length of left mandible: 0.70 mm. Length of pronotum: 0.50–0.55 mm. Length of hind tibia: 0.55 mm. Width of head (at widest part): 0.85 mm. Width of pronotum: 0.70–0.75 mm.

TYPE LOCALITY.—Barro Colorado Island, Canal Zone, Panama.

Described from two soldiers and one deälated adult collected with nymphs at the type locality by I. Molino and T. E. Snyder on February 21, 1924, in a decaying branch lying on the ground in moist jungle. This species was named in honor of Dr. Thos. Barbour, of the Museum of Comparative Zoology, Cambridge, Mass.

TYPE, SOLDIER.—Cat. No. 27269, U. S. National Museum; morphotype, deälated adult.

Kalotermes (Glyptotermes) emarginicollis, new species.

SOLDIER.—Head light castaneous brown, yellow-brown on sides and posteriorly, reddish brown to blackish anteriorly, front blackish, nearly vertical, head longer than broad, broadest posteriorly, sides approximately parallel, constricted on top of head anteriorly, rim elevated, front deeply bilobed medially with a wide U-shaped cut, lobes not roughened, surface of head smooth, with few scattered long hairs. Eye spot hyaline, large, somewhat projecting, suboval, parallel to front of head.

Mandibles blackish, base reddish brown, short, stout, incurved at apex; left mandible with three pointed marginal teeth; right mandible with two prominent pointed marginal teeth.

Antennae white with tinge of yellow, of twelve segments, segments wedge-shaped, becoming longer and broader toward apex, with long hairs; third segment ringlike, shorter than second or fourth segments; last segment slender, subelliptical, pointed at apex.

Pronotum light yellow-brown, darker on margins, margins deeply roundly emarginate, corners high anteriorly and roundly sloping posteriorly, with scattered long hairs (fig. 5, *c*).

Legs yellowish, femora slightly darker dorsally, swollen, three prominent reddish brown spines on tibia of front legs at apex, with hairs; prosternal processes dark (castaneous).

Abdomen dirty gray-white with yellowish tinge; tergites with dense short hairs and a row of long hairs at base of each tergite; cerci present but not prominent.

MEASUREMENTS.—Length of entire soldier: 5.50 mm. Length of head with mandibles: 2.50–2.60 mm. Length of head to anterior margin: 2.10–2.20 mm. Length of left mandible: 0.90. Length of pronotum: 0.80–0.90 mm. Length of hind tibia: 0.85 mm. Width of head: 1.40–1.55 mm. Width of pronotum: 1.40 mm.

TYPE LOCALITY.—Rio Chinilla, Canal Zone, Panama.

The specific name is derived from the emarginate pronotum of the soldier; this is a larger species than *K.* (*G.*) *pubescens* Snyder of Porto Rico and the soldier has a markedly emarginate pronotum.

Described from a series of soldiers collected with nymphs in a decaying log on the ground at the type locality by T. E. Snyder and I. Molino, on February 22, 1924.

TYPE, SOLDIER.—Cat. No. 27268, U. S. National Museum.

Cornitermes acignathus Silvestri.

DEÄLATED MALE ADULT.—Head castaneous, round, with a hyaline, suboval, raised fontanelle, in a depression (larger than an ocellus); head with few scattered long hairs. Eye black, large projecting, not quite round, very near lateral margin of head. Ocellus hyaline, large, suboval, upper rim projecting, separated from eye by a distance about one-half the small diameter of an ocellus.

Antennae yellow-brown, 15-segmented, with long hairs; third segment subclavate, longer than second or fourth segments; last segment slender, subelliptical.

Pronotum same color as head, anterior margin straight, posterior margin emarginate, narrowing posteriorly, hyaline "spread-wing"-shaped markings, anteriorly centering on median line, an elliptical marking at each anterior corner, and two elliptical markings near posterior margin separating from a common base at the median line to form an acute angle, diverging from the median line toward the sides; with dense long hairs.

Legs yellow-brown, tibiae darker, elongate, slender, pubescent.

Abdomen with tergites castaneous, two spiracular, hyaline markings about one-third way toward median line, one at each side in center of tergite (more prominent than in *C. striatus* Hagen), with long hairs near base of tergites, cerci not very prominent.

MEASUREMENTS.—Length of entire deälated male adult: 8.50 mm. Length of head: 2.15 mm. Length of pronotum: 1.05 mm. Diameter of eye (long diameter): 0.70 mm. Diameter of hind tibia: 2.60 mm. Width of head (at eyes): 2.15 mm. Width of pronotum: 2.00 mm. Length of mature queen: 18.50 mm. Width of abdomen of mature queen: 6.50 mm.

The deälated adult of *C. acignathus* is lighter colored, and larger than that of *C. striatus* Hagen, with larger fontanelle and eyes, ocellus more distant from eye, and markings on pronotum different. The species *C. acignathus* has been hitherto known only from the soldier caste from which it was described by Silvestri in 1903, although Nathan Banks states that the adult is similar to *C. striatus*, with a slender fontanelle.

Described from mature, deälated males and females (kings and queens) of the first form collected at Rio Tapia, Republic of Panama, on February 7, 1924, by the writer with soldiers and workers in decayed logs on the ground in the jungle. Other specimens were collected by the writer at Rio Chinilla, Canal Zone, Panama, on February 22, 1924. These specimens are all deposited in the collection of the United States National Museum.

Armitermes (Armitermes) chagresi, new species.

SOLDIER.—Head light yellow, nearly as broad as long, head and nasus not convex in profile, slightly concave at base of nasus, sides convex, broadest near posterior margin, narrowed anteriorly; with scattered long hairs. Nasus light yellow-brown, fairly robust, broad at base, narrowing anteriorly, dense short hairs at apex, not as long as head (in *A. armigera* Motschulsky nasus is longer than head). Mandibles slender and strongly curved, with slightly outward pointing marginal tooth nearer base than apex (fig. 6).

Antennae light yellow-brown, of 14 segments, pubescent, extending far beyond tip of nasus; third segment subclavate, longer than second or fourth segments; segments becoming longer and broader toward apex; last segment short, slender, subelliptical. Gula not much narrowed in middle.

Pronotum white, tinged with yellow, saddle-shaped, emarginate anteriorly, sides sloping roundly to posterior margin, which is rounded, with scattered long hairs.

Legs tinged with yellow, fairly elongate, slender, pubescent.

Abdomen tinged with yellow, densely pubescent; cerci prominent.

MEASUREMENTS.—Length of entire soldier: 5.50–5.65 mm. Length of head with nasus: 2.30–2.40 mm. Length of head with mandibles: 2.40–2.50 mm. Length of head to anterior margin: 1.50 mm. Length of nasus: 0.85 mm. Length of left mandible: 1.10 mm. Length of pronotum: 0.35 mm. Length of hind tibia: 1.30 mm. Width of head (at widest point posteriorly): 1.35–1.40 mm. Width of head at anterior margin: 0.95 mm. Width of pronotum: 0.75 mm.

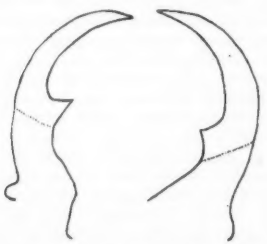


FIG. 6.—*Armitermes* (*Armitermes*) *chagresi:* Mandibles of soldier, showing marginal teeth. (From drawing made by camera lucida)

Specimens of *A.* (*A.*) *chagresi* Snyder were first found at Barro Colorado Island, Canal Zone, on February 21, 1924, by T. E. Snyder in a carton nest on the ground in the jungle (Pl. 2, C, D). Formerly *A.* (*A.*) *armigera* Motschulsky was considered to be the only species in Panama; it was described from Obispo and I have seen the type at the Museum of Comparative Zoology, Cambridge, Mass.; *chagresi* is close to *neoleinicus* Holmgren and *percutiens* Emerson; the antennae are also different from those in *armigera*. Specimens of *chagresi* were also collected at Rio Chinilla, Canal Zone, on February 22, in a carton nest and in decaying logs; in these specimens the nasus is slightly longer and the head and nasus tend toward the convex in profile. In the genus Armitermes there appear to be either a large number of closely related species or much variation within the species.

TYPE LOCALITY.—Barro Colorado Island, Canal Zone, Panama.

Described from a series of soldiers collected with workers at the type locality by T. E. Snyder on February 21, 1924.

TYPE, SOLDIER.—Cat. No. 27357, U. S. National Museum.

GENUS ARMITERMES WASMANN

SUBGENUS RHYNCHOTERMES HOLMGREN

In 1912, Holmgren established the subgenus Rhynchotermes for Silvestri's remarkable species *nasutissimus* from South America; this subgeneric name, derived from the Greek ῥύγχος (beak), is very appropriate and descriptive. This subgenus is monotypic. A much more striking and longer-beaked species has recently been found in Panama; the marginal teeth to the mandibles of the soldier are elongate and sharp-pointed and the anterior process on the coxa of the forelegs is more bent and hook shaped. It is a thoroughly armed species and runs about audaciously with its nasus or beak elevated at an angle of 45°, reminding one of an antiaircraft gun.

Armitermes (Rhynchotermes) perarmatus, new species.

SOLDIER (fig. 7). Head light castaneous brown, middle of beak and mandibles reddish brown, head short, pear-shaped, nasus very elongate, curved downward and becoming gradually attenuated toward apex; one row of hort hairs on head anteriorly. Mandibles very short, bent inward or hook-shaped, inner margin near tips not crenulate, near center of each mandible a long, outward-curved, sharp-pointed marginal tooth.

Antennae yellow-brown, elongate, slender, of 14 segments, with long hairs; third segment subclavate, as long as first, longer than second or fourth; fourth segment longer than second; fifth segment longer than fourth; segments gradually becoming shorter but broader toward apex; last segment subelliptical.

Pronotum light yellow-brown, darker on margins, saddle-shaped, slightly broader than long, high and roundly narrow at anterior margin, where emarginate, broadly rounded posteriorly.

Legs with tinge of yellow, elongate, with scattered long, but sparse, hairs, coxa of foreleg with an elongate point or sharp process, sometimes hook shaped and curving; two spines at apex of tibia.

Abdomen dirty gray-white, with tinge of yellow, with row of long hairs at base of each tergite.

MEASUREMENTS.—Length of entire soldier: 4.50–4.60 mm. Length of head with nasus: 2.50–2.60 mm. Length of head with mandibles: 1.20 mm. Length of head to anterior margin: 1.00 mm. Length of nasus: 1.60 mm. Length of left mandible: 1.05 mm. Length of pronotum: 0.40 mm. Length of hind tibia: 1.50 mm. Width of head (at widest portion): 0.90–0.95 mm. Width of pronotum: 0.55 mm.

The soldier of *A.* (*R.*) *perarmatus* is darker colored, larger than *nasutissimus* Silvestri, and has a longer, more aquiline head and nasus, longer mandibles, and long, pointed marginal teeth. The antennae have longer segments, and the process on the coxae is longer and more pointed.

WORKER.—Darker colored and larger than that of *nasutissimus;* head yellow-brown, with prominent fontanelle; antennae with 14 segments; postclypeus bulging.

MEASUREMENTS.—Length of entire worker: 4.1 mm. Length of head: 1.50 mm. Length of pronotum: 0.45 mm. Length of hind tibia: 1.50 mm. Width of head: 1.30 mm. Width of pronotum: 0.70 mm.

The winged adult is unknown.

TYPE LOCALITY.—Rio Chinilla, Canal Zone, Panama.

Described from a large series of soldiers and workers collected in a decayed log on February 22, 1924, at the type locality by I. Molino, J. Zetek, and T. E. Snyder; two colonies collected.

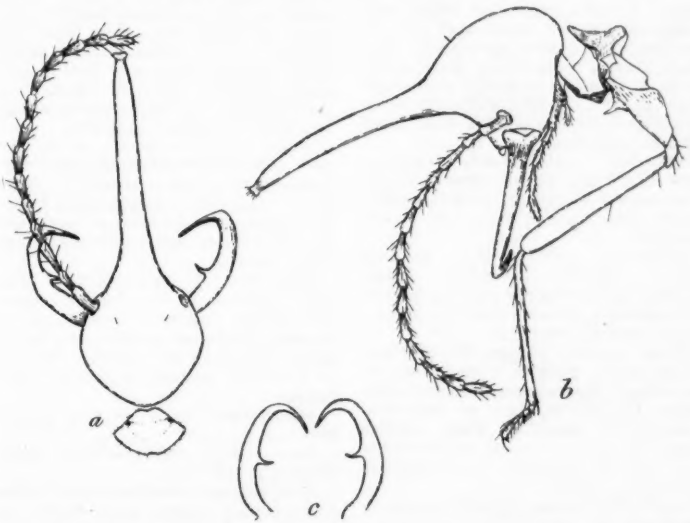


FIG. 7.—*Armitermes* (*Rhynchotermes*) *perarmatus*, soldier: *a*, Dorsal view of head and prothorax, showing long nasus and pointed marginal teeth of mandibles; *b*, lateral view of same, showing elongate, curved nasus, mandible, coxal spine of long foreleg, and antenna; *c*, dorsal view of mandibles

TYPE, SOLDIER.—Cat. No. 27240, U. S. National Museum.

BIOLOGICAL NOTES.—This termite lives in bark-covered decaying logs in the moist, dense jungle; it was not found in earthlike carton nests. Sometimes several other species of termites inhabit the same log, as *Coptotermes niger* Snyder and *Rhinotermes longidens* Snyder. A species of Peripatus was also found in a log inhabited by *A.* (*R.*) *perarmatus* (Pl. 1, A).

Dr. W. M. Mann found specimens of this termite at Sangrelaya, Honduras, in May, 1924, under bark in a decayed log in the jungle.

A single winged male adult of a species of Rhynchotermes was collected

flying by August Busck at Paraiso, Canal Zone, Panama, on April 24, 1911, and is now in the collection of the United States National Museum. This may be *Armitermes* (*Rhynchotermes*) *perarmatus*, as *perarmatus* is the only species so far collected in Panama. *A.* (*R.*) *nasutissimus* Silvestri of South America appears to be different. It is not *A.* (*Armitermes*) *armigera* Motschulsky, as it was tentatively and doubtfully determined by Nathan Banks in 1918.

WINGED MALE ADULT.—Head castaneous brown, longer than broad, rounded posteriorly, with a few scattered long hairs. Fontanelle hyaline, tinged with yellowish, a raised round spot in a depression, smaller than an ocellus. Eye black, large, projecting, not round; ocelli hyaline, elongate, projecting, close to eyes, on rim of frontal slope. Postclypeus lighter colored than head, bilobed, projecting.

Antennae yellow-brown (broken), with long hairs; third segment longer than second or fourth; fourth slightly longer than second; fifth and fourth subequal.

Pronotum yellow-brown, anterior margin slightly elevated, nearly straight, sides roundly sloping to posterior margin, which is broadly rounded and emarginate.

Wings smoky yellow, costal veins golden yellow, margins ciliate, wing surface *hairy*. Forewing with median vein nearer to cubitus than to subcosta, branching to apex of wing, cubitus nearly in center of wing, not reaching apex, with 11 branches or sub-branches to margin of wing.

Legs yellow-brown, slender, elongate, pubescent.

Abdomen light yellow-brown, with a row of dense long hairs at base of each tergite; cerci fairly prominent.

MEASUREMENTS.[3]—Length of entire winged adult: 15.00 mm. Length of entire deälated adult: 7.00 mm. Length of head: 1.90 mm. Length of pronotum: 0.80 mm. Length of forewing: 13.00 mm. Length of hind tibia: 2.00 mm. Diameter of eye (long diameter): 0.45 mm. Width of head (at eyes): 1.60 mm. Width of pronotum: 1.40 mm. Width of forewing: 4.80 mm.

The wing is hairy, whereas that of *A.* (*R.*) *nasutissimus* Silvestri is *not* hairy. *A.* (*R.*) *perarmatus* also has longer hind tibiae than *nasutissimus*. Comparison was made with a winged male adult of *nasutissimus* determined by F. Silvestri and donated by him to the United States National Museum, No. 47.

Nasutitermes (Obtusitermes) biformis Snyder.

DEÄLATED ADULT.—Head dark brown, with a reddish tinge, suboval, fairly flat, a narrow slope toward anterior margin, with dense, long hairs. Fontanelle a hyaline, narrow slit in a depression on vertex at about middle of eyes. Eyes black, nearly round, prominent, very near lateral margin of head; ocelli hyaline, suboval, fairly large, inset, at an oblique angle to eyes and separated from eyes by a distance less than the small diameter of an ocellus. Left mandible reddish-brown, first and second teeth approximately subequal. Postclypeus yellow-brown, not prominently arched, length less than half the width.

Antennae yellow-brown, of thirteen (+?) segments, with long hairs; third segment very short, ringlike; fourth shorter than second; segments becoming longer and broader toward apex, but all more or less wedge-shaped and fairly short.

Pronotum of same color as head, very slightly saddle-shaped, almost subcordate, anterior margin almost straight, posterior margin emarginate, sides rounded and sloping roundly to posterior margin, with dense long hairs.

Wing scale nearly as long as pronotum.

Legs light yellow-brown, fairly slender, pubescent.

Abdomen with tergites slightly lighter colored than head, with dense long hairs; cerci fairly prominent.

MEASUREMENTS.—Length of entire deälated adult: 5.50 mm. Length of head: 1.00 mm. Length of pronotum: 0.50. Length of hind tibia: 0.80 mm. Diameter of eye (long diameter): 0.25 mm. Width of head (at eyes): 0.95 mm. Width of pronotum: 0.70 mm.

Described from two deälated colonizing adults (male and female) collected in a small cavity in a decayed branch on the ground at Barro Colorado Island, Canal Zone, by J. Zetek and I. Molino on August 22, 1923; they are probably a young royal couple. *O. biformis* was described in 1924 from the soldier caste alone, the type locality being Quipo, Republic of Panama; these specimens were not found with soldiers, but soldiers and workers were in the branch,

[3] They were made from a dry, pinned specimen.

and are the only dealated adults of this species that have been collected; they are deposited in the collection of the United States National Museum. The winged adult is unknown.

GENUS NASUTITERMES BANKS

SUBGENUS UNIFORMITERMES, NEW SUBGENUS

In Panama another species of Nasutitermes has been found that does not agree with the characters of any known subgenus; this species, with others from Bolivia, intermediate between Diversitermes Holmgren and Velocitermes Holmgren, throws considerable doubt on the validity of subgenera in Nasutitermes. For the present, however, I prefer to adhere to the subgenera established by Holmgren and others; possibly this species is a Diversitermes.

Uniformitermes, new subgenus.

SOLDIER.—Two types of soldiers, but of somewhat the same general form, in each form head markedly constricted behind antennae. Nasus elongate, slender, cylindrical. Mandibles with points, sharp but not very elongate. The shape of the major soldier is somewhat similar to that of the minor soldier of Diversitermes, while that of the minor soldier is similar to that of the intermediate soldier of Diversitermes.

Outline of head of major soldier in general similar to that of the soldier of Tenuirostritermes Holmgren, pear shaped and markedly broader posteriorly than anteriorly. In major soldier antennae with thirteen segments; in minor, twelve segments. Legs relatively short, length of hind tibia much less than length of head with nasus.

Postclypeus of *worker* nearly as long as half its width.

Small, light colored species.

Nasutitermes (Uniformitermes) barrocoloradensis, new species.

MAJOR SOLDIER (fig. 8, *a*, *b*).—Head pale yellowish, darker at margins and at base of nasus, nasus reddish, head pyriform, broadest posteriorly, gradually converging toward anterior margin, breadth more contrasting posteriorly and anteriorly than in minor soldier, markedly but not sharply constricted anteriorly, convex in profile except for slight depression about center of head, with numerous short hairs, but with few long hairs anteriorly and posteriorly. Nasus elongate, slender, cylindrical, slightly upturned at apex, with short hairs and a few long hairs at apex. Mandibles fairly short, sharp pointed, points turned outward.

Antennae light yellow-brown, of thirteen segments, with long hairs; third segment subclavate, slender, longer than second or fourth segments; fourth segment shorter than second; fifth longer and broader than fourth; sixth, seventh, and eighth segments longer and broader than fifth; segments becoming shorter toward apex; last segment slender and subelliptical.

Pronotum yellow, darker at anterior margin, saddle-shaped, with short hairs, broadly rounded anteriorly and posteriorly, sides slightly depressed posteriorly, slightly emarginate at anterior margin.

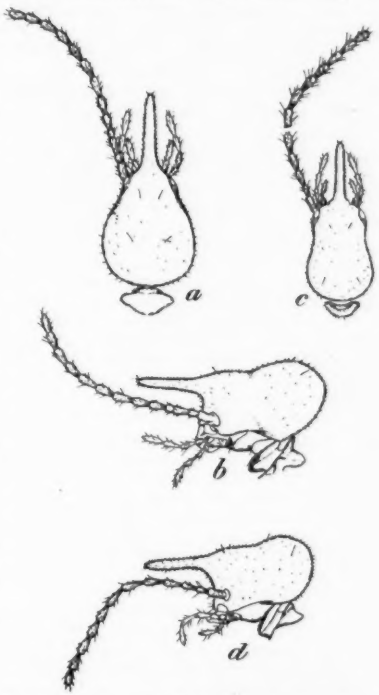


FIG. 8.—*Nasutitermes* (*Uniformitermes*) *barrocoloradensis*: *a*, Dorsal view of head and pronotum of major soldier; *b*, lateral view of same; *c*, dorsal view of head and pronotum of minor soldier; *d*, lateral view of same

Legs with tinge of yellow, fairly elongate, slender, and with long hairs.

Abdomen dirty gray-white with tinge of yellow, tergites with short hairs and a row of long hairs at base of each tergite; cerci fairly prominent.

MEASUREMENTS (MAJOR SOLDIER).—Length of entire soldier: 3.1–3.3 mm. Length of head with nasus: 1.40–1.50 mm. Length of head to anterior margin: 0.90–1.00 mm. Length of nasus: 0.50–0.55 mm. Length of pronotum: 0.20 mm. Length of hind tibia: 1.10 mm. Width of head (where widest posteriorly): 0.70–0.80 mm. Width of head anteriorly: 0.40 mm. Width of pronotum: 0.40 mm.

MINOR SOLDIER (fig. 8, *c*, *d*).—Head pale yellowish, darker at margins and at base of nasus, nasus reddish, head somewhat pyriform, broadest posteriorly, gradually converging toward anterior margin, not as great a difference in breadth posteriorly and anteriorly as in major soldier, somewhat dumbbell shaped, markedly but not sharply constricted anteriorly, convex in profile except for slight depression about center of head, with numerous short hairs, but with few long hairs anteriorly and posteriorly. Nasus elongate, slender, cylindrical, slightly upturned at apex, with short hairs, a few long hairs at apex. Mandibles fairly short, sharp pointed, with points turned outward.

Antennae light yellow-brown, elongate, of twelve segments, with long hairs; third segment subclavate, longer than second but shorter than fourth; fifth about as long as fourth but broader; sixth longer than fifth; seventh slightly shorter than sixth; segments becoming shorter but broader toward apex; last segment more slender, subelliptical.

Pronotum pale yellow, anterior margin darker, saddle-shaped, with short hairs, margins broadly rounded anteriorly and posteriorly, sides slightly depressed posteriorly.

Legs with tinge of yellow, fairly elongate, slender and with long hairs.

Abdomen dirty gray-white with tinge of yellow, with short hairs on tergites and one row of long hairs at base of each tergite.

MEASUREMENTS (MINOR SOLDIER).—Length of entire soldier: 2.75–3.00 mm. (aver. 2.90 mm.). Length of head with nasus: 1.10–1.175 mm. Length of head to anterior margin: 0.75 mm. Length of nasus: 0.41 – 0.45 mm. Length of pronotum: 0.15 mm. Length of hind tibia: 0.90 mm. Width of head (where widest posteriorly): 0.50 mm. Width of head anteriorly: 0.40 mm. Width of pronotum: 0.25 mm.

Winged adult unknown.

TYPE LOCALITY. — Barro Colorado Island, Canal Zone, Panama.

Described from a large series of major and minor soldiers collected by T. E. Snyder with workers in a large colony at the type locality on February 26, 1924. Several colonies were found in decaying logs, with bark on, near the site of the new Tropical Research Station building.

TYPE, MAJOR SOLDIER.—Cat. No. 27270, U. S. National Museum; morphotype, minor soldier.

Mirotermes (Mirotermes) panamaensis Snyder.

DEÄLATED ADULT (MALE OR KING).—Head light yellow-brown, lighter posteriorly, suboval, longer than broad, not as broad as pronotum, with scattered long hairs, more numerous anteriorly, postclypeus light yellow, slightly bulging, twice as broad as long, prominently bilobed. Eyes black, fairly prominent, nearly round, separated from lateral margin of head by a distance less than their long diameter. Ocelli hyaline, suboval, separated from eyes by a distance hardly equal to the long diameter of an ocellus. Fontanelle, a hyaline narrow elliptical slit between middle of eyes.

Antennae light yellow-brown, of fifteen segments, with long hairs, becoming longer and broader toward apex; third segment very small, shorter than second or fourth segments, ringlike; fourth shorter than second segment; fifth ringlike, shorter than fourth; last segment elongate, slender, subelliptical.

Pronotum light yellow-brown, darker posteriorly, anterior and posterior margins nearly straight, slightly concave anteriorly and slightly emarginate posteriorly, sides rounded, sloping slightly to posterior margin, with long hairs.

Wing scale much shorter than pronotum.

Legs light yellow-brown, slender, with long hairs.

Abdomen with tergites brown, darker colored than head and pronotum, with fairly long hairs, lighter anteriorly; cerci prominent.

MEASUREMENTS.—Length of entire deälated adult (mature first-form male or king): 4.00 mm. Length of mature, deälated queens of the first form (with distended abdomens): 5.5–7.0 mm.; average, 6.76 mm. Length of head: 1.00 mm. Length of pronotum: 0.55 mm. Length of hind tibia: 0.70 mm. Diameter of eye: 0.16 mm. Width of head (at eyes): 0.85 mm. Width of pronotum: 0.95 mm. Width of abdomen of male: 1.40 mm. Width of abdomen of queens: 2.5–2.8 mm.; average, 2.65 mm.

King with abdomen slightly distended but queens with abdomens markedly distended and a flat quadrilateral shape.

Described from one male (mature, deälated, first-form adult or king) and nine females (mature, deälated, first-form adults with distended abdomens) collected with soldiers and workers in a very large colony in a decaying, fallen coconut palm tree trunk on the ground on a slight elevation near a mangrove swamp on February 19, 1924, at Largo Remo Island, Canal Zone, by T. E. Snyder and J. Zetek. These reproductive forms were in a small (about 7 inches wide) ovoid carton nest on the side of the interior of the log (Pl. 1, C and D).

M. (*Mirotermes*) *panamaensis* Snyder was described in 1923 from the soldier caste alone (fig. 9), the type locality being Barro Colorado Island, Canal Zone. This is the first time the sexual form or deälated adult has been collected; the winged form has not yet been found. The specimens are deposited in the collection of the United States National Museum.

LIST OF TERMITES OF THE CANAL ZONE AND NEAR-BY PANAMA

KALOTERMITIDAE: (100)

1. *Kalotermes tabogae* Snyder
2. *Kalotermes marginipennis* Latreille
3. *Kalotermes panamae* Snyder
4. *Neotermes holmgreni* Banks
5. *Kalotermes* (*Lobitermes*) *brevicollis* Banks
6. *Cryptotermes dudleyi* Banks (*Cryptotermes thompsonae* Snyder)
7. *Kalotermes* (*Lobitermes*) *longicollis* Banks
8. *Kalotermes* (*Glyptotermes*) *angustus* Snyder
9. *Kalotermes* (*Glyptotermes*) *emarginicollis* Snyder
10. *Kalotermes* (*Glyptotermes*) *barbouri* Snyder

RHINOTERMITIDAE: (5)

11. *Coptotermes niger* Snyder
12. *Leucotermes tenuis* Hagen
13. *Leucotermes convexinotatus* Snyder
14. *Prorhinotermes molinoi* Snyder
15. *Rhinotermes longidens* Snyder

TERMITIDAE: (21)

16. *Cylindrotermes nordenskiöldi* Holmgren
17. *Amitermes medius* Banks
18. *Amitermes beaumonti* Banks
19. *Cornitermes acignathus* Silvestri
20. *Armitermes* (*Armitermes*) *armigera* Motschulsky
21. *Armitermes* (*Armitermes*) *chagresi* Snyder
22. *Armitermes* (*Rhynchotermes*) *perarmatus* Snyder
23. *Nasutitermes cornigera* Motschulsky
24. *Nasutitermes pilifrons* Holmgren
25. *Nasutitermes ephratae* Holmgren
26. *Nasutitermes columbicus* Holmgren

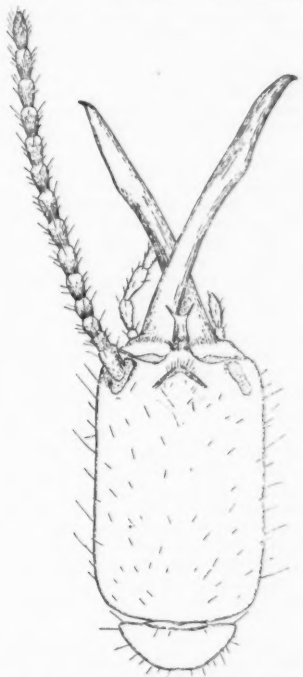


FIG. 9.—*Mirotermes* (*Mirotermes*) *panamaensis*: Dorsal view of head and pronotum of soldier

27. *Nasutitermes* (*Uniformitermes*) *barrocoloradensis* Snyder
28. *Nasutitermes* (*Subulitermes*) *zeteki* Snyder
29. *Nasutitermes* (*Obtusitermes*) *biformis* Snyder
30. *Anoplotermes gracilis* Snyder
31. *Anoplotermes parvus* Snyder
32. *Eutermes debilis* Heer=*arboreus* Emerson
33. *Eutermes exiguus* Hagen
34. *Mirotermes* (*Mirotermes*) *hispaniolae* Banks
35. *Mirotermes* (*Mirotermes*) *panamaensis* Snyder
36. *Orthognathotermes wheeleri* Snyder

Occurring on Barro Colorado Island, C. Z., the site of the Panama laboratory of the Institute for Research in Tropical America; there occur here twenty species and fifteen genera or subgenera.

THE SHAPE AND WEIGHT OF EGGS IN RELATION TO THE SEX OF CHICKS IN THE DOMESTIC FOWL [1]

By M. A. Jull, *Senior Poultryman*, and J. P. Quinn, *Poultryman, Bureau of Animal Industry, United States Department of Agriculture*

REVIEW OF PREVIOUS WORK

A study of the causes that might affect the production of one sex or the other in the domestic fowl should have an important bearing on the practical aspects of the poultry industry and on current theoretical questions concerning sex determination. The senior author [2] has made a number of observations concerning the sex-ratio situation in the domestic fowl, including the following:

1. There is no apparent correlation between egg weight and sex ratio.

2. There is no apparent correlation between yolk weight and sex ratio.

3. There is no apparent correlation between yolk water-content and sex ratio.

The authors are not aware of any observations having been made concerning the relationship between the shape of the egg and the sex of the chick hatched from it. A solution of this problem is important in order that the result may be added to results already determined and also because of the prevailing opinion among many practical poultrymen that long eggs usually produce male chicks. The poultry office of the Animal Husbandry Division of the United States Department of Agriculture is continually receiving letters either stating that the longer eggs produce more males than the shorter ones or inquiring if such is not the case. The data presented in this study serve as an answer.

The data in this study also deal with the relationship between the weight of the egg and the sex of the chick hatched from it. It has been stated above that the senior author found no correlation to exist between egg weight and sex ratio. This observation was based upon the results obtained in determining the sex of chicks from eggs laid during the first year of production by 45 Barred Plymouth Rock pullets mated to Brown Leghorn males. The sex was determined of all embryos that died from the twelfth day to hatching time as well as of all chicks that hatched. There was found to be no correlation between weight of egg and sex of chick.

On the other hand, in another study the senior author [3] found a significant difference between the weights of eggs from which males were obtained and those from which females were obtained. This was based upon data used in a determination of growth rates in the sexes of pure-bred Barred Plymouth Rock chicks. The only egg weights taken into consideration were those producing the chicks on which growth rates were determined, the records for analysis being selected at the conclusion of the growth period. The weights of the eggs in which embryos died and the weights of the eggs producing chicks which died prior to the termination of the period of growth studied were not considered. From the sex standpoint there may have been a differential prenatal or a differential postnatal mortality, or both. The weights of the eggs producing the chicks which completed the growth test showed that the eggs which produced males were heavier than the eggs which produced females, 52.11 ± 0.41 and 50.05 ± 0.53 gm. The difference in mean weights is 2.06 ± 0.67 gm., a difference which is slightly more than three times its probable error and therefore barely significant.

The case in which there was established no correlation between egg weight and chick sex was with eggs laid throughout the first year of production

[1] Received for publication June 23, 1924—issued January, 1925.

[2] JULL, M. A. THE RELATION OF ANTECEDENT EGG PRODUCTION TO THE SEX RATIO IN THE DOMESTIC FOWL. Jour. Agr. Research, XXVIII: 199-224, 1924.

[3] JULL, M. A. DIFFERENTIAL SEX GROWTH CURVES IN BARRED PLYMOUTH ROCK CHICKS. Sci. Arg. 4: 58-65, illus. 1923.

of each of 45 pullets, while the case in which there was a difference in the mean weights of eggs producing the two sexes was with eggs laid during the normal hatching season.

In view of the apparently different results obtained in the latter case, it was thought advisable to make additional studies, particularly with eggs laid during the normal hatching season.

EGG SHAPE IN RELATION TO CHICK SEX

The eggs of 24 Barred Plymouth Rock pullets laid between the middle of February and the last of April were measured carefully at the time of laying. The length and maximum breadth of each of 990 eggs were measured in millimeters, the measurements being recorded to hundredths of a millimeter. The sex of the chicks was determined by dissection at hatching time.

In Table I is shown the frequency distribution in terms of length in millimeters of the eggs producing males and those producing females. Of the 990 eggs, 512 produced males and 478 produced females. The mean length of the eggs producing males is 55.31 ± 0.06 mm. and the mean length of the eggs producing females is 55.42 ± 0.07 mm. The eggs producing females have a mean length slightly greater than that of the eggs producing males, but the difference is not at all significant since it is only 0.11 ± 0.09, as shown in Table VIII. The variation in length, both absolutely and relatively, is quite small in each group of eggs producing males and females. In Table II the production of each pullet is considered separately and there is not a single case in which the mean length of eggs producing males and those producing females is significantly different. Moreover, among the 24 pullets there are 13 in which the mean length of eggs producing males is greater than the mean length of eggs producing females and 11 in which the reverse is the case. It can be said, therefore, that there is no relation between length of egg and the sex of the chick hatched from it.

The shape of an egg is determined by considering the length and breadth in relation to each other. The length-breadth index was used as a measure of shape and was obtained by dividing one hundred times the breadth by the length. A long and narrow egg has a relatively low index, while a short and broad egg has a high index. Based on the assumption that long eggs usually produce a preponderance of males, it should be expected that eggs producing males would have a lower index than eggs producing females. The frequency distribution of shape index and the relative mean indexes of eggs producing males and females, respectively, are shown in Table III. The mean index of eggs producing males is 75.17 ± 0.09 and the mean index of eggs producing females is 75.09 ± 0.10, the difference with its probable error being 0.08 ± 0.13, as shown in Table VIII.

There is very little difference in respect to the relative and absolute amounts of variability between the groups of eggs producing the two sexes. In Table IV the mean indexes of eggs producing males and females, respectively, are shown for each pullet and in no case is the difference in the mean index significant. It is apparent, therefore, that there is no correlation between the relative length of an egg and the sex of the chick hatched from it. In other words, long and narrow eggs having relatively low indexes as compared with short, broad ones, are not likely to produce male chicks in any greater proportion than eggs with relatively high indexes.

EGG WEIGHT IN RELATION TO CHICK SEX

Eggs from two different sources were used in this study of egg weight in relation to the sex of chicks. In the first case eggs were obtained from 153 Barred Plymouth Rock females mated to Rhode Island Red males and in the second case from 58 Rhode Island Red females mated to Rhode Island Red males. The weights of 418 and 226 eggs in the former and latter cases, respectively, are taken into consideration, making a total of 644 eggs. The eggs were weighed daily as laid, the weights being recorded to hundredths of a gram.

TABLE I.—*Frequency distribution of egg length and the relative mean length of eggs producing males and females, respectively*

Egg length	Eggs producing—		
	Males	Females	Total
Mm.			
50.00 to 50.99	6	8	14
51.00 to 51.99	18	15	33
52.00 to 52.99	25	25	50
53.00 to 53.99	68	65	133
54.00 to 54.99	77	75	152
55.00 to 55.99	87	83	170
56.00 to 56.99	86	80	166
57.00 to 57.99	65	61	126
58.00 to 58.99	47	37	84
59.00 to 59.99	18	16	34
60.00 to 60.99	15	10	25
61.00 to 61.99		3	3
Total	512	478	990
Mean length	55.31±0.06	55.42±0.07	55.37±0.04
Standard deviation	2.18±0.05	2.17±0.05	2.17±0.03
Coefficient of variability	6.81±0.14	7.02±0.12	3.92±0.06

TABLE II.—*Mean egg length per bird for eggs producing males and females respectively*

Pullet No.	Eggs producing males		Eggs producing females		Difference
	Number	Mean length	Number	Mean length	
		Mm.		*Mm.*	*Mm.*
1	16	54.83±0.18	9	54.36±0.14	0.47±0.23
2	14	54.32±0.16	14	54.64±0.13	0.32±0.21
3	18	54.96±0.16	16	55.21±0.15	0.15±0.22
4	11	55.06±0.21	15	55.18±0.19	0.12±0.28
5	13	57.21±0.18	16	56.84±0.12	0.33±0.22
6	14	54.30±0.20	14	54.27±0.17	0.03±0.26
7	17	56.58±0.17	13	57.21±0.21	0.63±0.27
8	26	55.42±0.16	20	55.30±0.12	0.12±0.20
9	25	55.13±0.14	24	55.25±0.16	0.12±0.21
10	29	54.72±0.22	18	53.84±0.18	0.88±0.30
11	17	54.34±0.16	17	54.94±0.17	0.60±0.23
12	36	54.87±0.13	35	54.74±0.22	0.13±0.25
13	19	58.62±0.19	16	57.93±0.22	0.69±0.29
14	36	57.79±0.23	36	58.40±0.14	0.16±0.27
15	20	54.90±0.14	38	54.69±0.11	0.31±0.18
16	14	56.67±0.18	15	57.01±0.15	0.34±0.23
17	18	55.39±0.17	14	55.25±0.21	0.14±0.27
18	32	55.08±0.13	12	55.17±0.14	0.09±0.16
19	25	56.72±0.12	25	56.55±0.19	0.17±0.22
20	27	54.37±0.14	26	54.57±0.20	0.20±0.24
21	35	55.11±0.18	36	54.98±0.23	0.13±0.29
22	8	55.44±0.21	11	55.26±0.22	0.18±0.30
23	27	57.23±0.11	17	57.01±0.14	0.22±0.18
24	15	54.86±0.15	21	55.23±0.18	0.37±0.23
Total	512	55.31±0.06	478	55.42±0.07	0.11±0.09

TABLE III.—*Frequency distribution of shape index and the relative mean indexes of eggs producing males and females, respectively*

Length-breadth index	Eggs producing—		
	Males	Females	Total
63.00 to 63.99		1	1
64.00 to 64.99			
65.00 to 65.99	1	2	3
66.00 to 66.99	3	3	6
67.00 to 67.99	5	5	10
68.00 to 68.99	9	10	19
69.00 to 69.99	16	16	32
70.00 to 70.99	20	22	42
71.00 to 71.99	31	25	56
72.00 to 72.99	40	37	77
73.00 to 73.99	49	53	102
74.00 to 74.99	62	53	115
75.00 to 75.99	70	66	136
76.00 to 76.99	59	56	115
77.00 to 77.99	57	51	108
78.00 to 78.99	35	38	73
79.00 to 79.99	29	16	45
80.00 to 80.99	12	12	24
81.00 to 81.99	7	5	12
82.00 to 82.99	3	4	7
83.00 to 83.99	3	0	3
84.00 to 84.99	1	3	4
Total	512	478	990
Mean index	75.17±0.09	75.09±0.10	75.13±0.07
Standard deviation	3.20±0.06	3.28±0.07	3.24±0.05
Coefficient of variability	4.26±0.09	4.37±0.09	4.31±0.06

TABLE IV.—*Mean egg length-breadth index per bird for eggs producing males and females, respectively*

Pullet No.	Eggs producing males		Eggs producing females		Difference
	Number	Mean length-breadth index	Number	Mean length-breadth index	
1	16	75.38±0.56	9	73.83±0.62	1.55±0.83
2	14	76.47±0.37	14	75.74±0.41	0.73±0.55
3	18	75.22±0.77	16	77.59±0.38	2.37±0.86
4	11	73.62±0.54	15	71.69±0.60	1.93±0.81
5	13	77.76±0.41	16	77.48±0.27	0.28±0.49
6	14	76.33±0.32	14	77.28±0.40	0.95±0.51
7	17	78.79±0.24	13	78.02±0.36	0.77±0.43
8	26	81.03±0.28	20	80.82±0.22	0.21±0.36
9	25	74.03±0.19	24	74.47±0.27	0.43±0.33
10	29	76.15±0.16	18	77.00±0.14	0.85±0.21
11	17	75.13±0.31	17	74.20±0.24	0.93±0.39
12	36	76.59±0.29	35	77.16±0.14	0.57±0.32
13	19	72.25±0.48	16	71.94±0.71	0.31±0.86
14	36	76.05±0.22	36	75.87±0.13	0.18±0.25
15	20	72.74±0.26	38	73.31±0.15	0.57±0.30
16	14	73.42±0.27	15	72.67±0.29	0.75±0.40
17	18	74.13±0.23	14	73.13±0.33	1.00±0.40
18	32	74.51±0.14	12	74.30±0.41	0.21±0.43
19	25	75.93±0.20	25	77.01±0.26	1.08±0.33
20	27	69.55±0.18	26	69.64±0.15	0.09±0.23
21	35	70.94±0.12	36	70.79±0.17	0.15±0.21
22	8	77.92±0.49	11	77.20±0.38	0.72±0.62
23	27	77.33±0.19	17	76.49±0.31	0.84±0.36
24	15	74.46±0.27	21	74.01±0.16	0.45±0.31
Total	512	75.17±0.09	478	75.09±0.10	0.08±0.13

TABLE V.—*Frequency distribution and mean weights of eggs producing male and female chicks, respectively, that hatched*

BARRED PLYMOUTH ROCK FEMALES MATED TO RHODE ISLAND RED MALES

Egg weight	Eggs producing—		
	Males	Females	Total
Grams			
47.00 to 47.99		2	2
48.00 to 48.99	1	1	2
49.00 to 49.99	3	0	3
50.00 to 50.99	1	0	1
51.00 to 51.99	2	2	4
52.00 to 52.99	2	4	6
53.00 to 53.99	4	5	9
54.00 to 54.99	19	14	33
55.00 to 55.99	16	16	32
56.00 to 56.99	14	13	27
57.00 to 57.99	26	17	43
58.00 to 58.99	22	15	37
59.00 to 59.99	20	16	36
60.00 to 60.99	13	15	28
61.00 to 61.99	10	8	18
62.00 to 62.00	6	7	13
63.00 to 63.99	10	8	18
64.00 to 64.99	6	2	8
65.00 to 65.99	9	3	12
66.00 to 66.99	3	3	6
67.00 to 67.99	2	2	4
68.00 to 68.99	1	4	5
Total	190	157	347
Mean weight	58.64±0.19	58.53±0.21	58.58±0.14
Standard deviation	3.83±0.13	3.92±0.15	3.95±0.10
Coefficient of variability	6.53±0.22	6.70±0.25	6.74±0.17

TABLE VI.—*Frequency distribution and mean weights of eggs producing male and female chicks, respectively, that died in shell at hatching time*

BARRED PLYMOUTH ROCK FEMALES MATED TO RHODE ISLAND RED MALES

Egg weight	Eggs producing—		
	Males	Females	Total
Grams			
49.00 to 49.99		1	1
50.00 to 50.99	1	3	4
51.00 to 51.99	0	1	1
52.00 to 52.99	1	0	1
53.00 to 53.99	2	2	4
54.00 to 54.99	2	1	3
55.00 to 55.99	6	4	10
56.00 to 56.99	4	3	7
57.00 to 57.99	2	6	8
58.00 to 58.99	2	2	4
59.00 to 59.99	4	10	14
60.00 to 60.99	1	1	2
61.00 to 61.99	1	1	2
62.00 to 62.99	0	1	1
63.00 to 63.99	2	2	4
64.00 to 64.99	1	2	3
65.00 to 65.99	1	0	1
66.00 to 66.99		0	0
67.00 to 67.99		0	0
68.00 to 68.99		1	1
Total	30	41	71
Mean weight	57.56±0.44	57.82±0.43	57.71±0.31
Standard deviation	3.56±0.31	4.09±0.30	3.92±0.22
Coefficient of variability	6.18±0.54	7.07±0.53	6.77±0.38

TABLE VII.—*Frequency distribution and mean weights of eggs producing male and female chicks, respectively, that hatched*

RHODE ISLAND RED FEMALES MATED TO RHODE ISLAND RED MALES

Egg weight	Eggs producing—		
	Males	Females	Total
Grams			
46.00 to 46.99		1	1
47.00 to 47.99		0	0
48.00 to 48.99		0	0
49.00 to 49.99	1	1	2
50.00 to 50.99	3	0	3
51.00 to 51.99	4	2	6
52.00 to 52.99	1	5	6
53.00 to 53.99	8	4	12
54.00 to 54.99	10	9	19
55.00 to 55.99	14	13	27
56.00 to 56.99	6	8	14
57.00 to 57.99	9	6	15
58.00 to 58.99	8	10	18
59.00 to 59.99	13	10	23
60.00 to 60.99	13	8	21
61.00 to 61.99	7	5	12
62.00 to 62.99	11	7	18
63.00 to 63.99	2	7	9
64.00 to 64.99	5	2	7
65.00 to 65.99	3	2	5
66.00 to 66.99	1	0	1
67.00 to 67.99	3	0	3
68.00 to 68.99	0	0	0
69.00 to 69.99	1	0	1
70.00 to 70.99	1	2	3
Total	124	102	226
Mean weight	58.06±0.26	57.29±0.27	57.75±0.19
Standard deviation	4.28±0.18	4.11±0.19	4.21±0.13
Coefficient of variability	7.37±0.31	7.17±0.33	7.29±0.23

TABLE VIII.—*Mean lengths, mean length-breadth indexes, and mean weights of eggs producing males and females, respectively*

Item	Eggs producing—		Difference
	Males	Females	
Mean length.....mm..	55.31±0.06	55.42±0.07	0.11±0.09
Mean length-breadth index	75.17±0.09	75.09±0.10	0.08±0.13
Mean weight Rock × Red, hatched.....gm...	58.64±0.19	58.53±0.21	0.11±0.28
Mean weight Rock × Red, died in shell.....do....	57.56±0.44	57.82±0.43	0.26±0.61
Mean weight Rock × Red, total.....do....	58.49±0.17	58.45±0.19	0.04±0.25
Mean weight Red × Red, hatched.....do....	58.06±0.26	57.29±0.27	0.77±0.37
Mean weight, all eggs.....do....	58.24±0.14	58.01±0.16	0.23±0.21

Of the 418 eggs from the Barred Plymouth Rock females, 347 hatched and 71 died in shell at hatching time. Distinguishing the sex of the chicks at hatching time was readily done, since the sex-linked barring pattern of the female parents is transmitted to the sons only. The male chicks, therefore, had the characteristic white spot on the back of the head and yellow shanks. The female chicks were solid black in down color and had very dark-colored or black shanks. Table V shows for the 347 chicks that hatched, the frequency distribution and the mean weights of the eggs producing males and females, respectively. The mean weight of the 190 eggs that produced males is 58.64±0.19 gm. and the mean weight of the 157 eggs that produced females is 58.53±0.21 gm. The difference in mean weight, with its probable error, is 0.11±0.28 and, therefore, is of no significance. There is very little difference in respect to the amount of variability, either relatively or absolutely, in the groups of eggs producing the two sexes. The same situation prevails in respect to the 71 eggs whose chicks died in shell at hatching time,

as shown in Table VI. The mean weight of the 30 eggs producing males is 57.56 ± 0.44 gm. and the mean weight of the 41 eggs giving rise to females is 57.82 ± 0.43 gm. The difference, with its probable error, is 0.26 ± 0.61 and, therefore, is not significant. When the weights of the eggs that hatched and the weights of the eggs whose chicks died in shell at hatching time are taken into consideration, it is found that the mean weight of the eggs producing males is 58.49 ± 0.17 gm. and the mean weight of the eggs producing females is 58.45 ± 0.19 gm. as shown in Table VIII. The difference, with its probable error, is 0.04 ± 0.25 and, therefore, is of no significance.

From the Rhode Island Red females there were secured 226 eggs that hatched and on which the sex of the chicks was later recorded. The frequency distribution and mean weights of the eggs producing males and females, respectively, are shown in Table VII. The mean weight of the eggs producing males is 58.06 ± 0.26 gm. and the mean weight of the eggs producing females is 57.29 ± 0.27 gm. The difference, with its probable error, as shown in Table VIII, is 0.77 ± 0.37 and, therefore, is not significant. The relative and absolute amounts of variability in both groups are quite small, as shown in Table VII.

The mean weights of all eggs from the Barred Plymouth Rock and Rhode Island Red females producing males and females, respectively, are shown in Table VIII. The mean weight of all eggs producing males is 58.24 ± 0.14 gm. and the mean weight of all eggs producing females is 58.01 ± 0.16 gm. The difference, with its probable error, is 0.23 ± 0.21 and, therefore, is not significant.

CONCLUSIONS

As a result of this study, the following observations apply to eggs produced during the normal hatching:

There is no correlation between the absolute length of egg and the sex of the chicks hatched from it.

There is no correlation between the relative length or shape of egg and the sex of the chick hatched from it.

There is no correlation between weight of egg and the sex of the chick hatched from it.

THE GROWING SEASON OF WESTERN YELLOW PINE [1]

By G. A. PEARSON

Director, Southwestern Forest Experiment Station, Forest Service, United States Department of Agriculture

Observations at the Southwestern Forest Experiment Station, at Flagstaff, Ariz., over a period of 14 years have shown that the shoots of western yellow pine, *Pinus scopulorum*, begin to grow about the middle of May, elongate most rapidly in June, and practically finish their growth by July 1. The major height growth occurs during the driest month of the year, although the lower soil strata are always moist from the heavy winter precipitation. Curiously enough, shoot growth is not resumed during the summer rainy season except occasionally in very vigorous seedlings. The needles continue to grow well into August. Does diameter growth take place at the same time as height growth or later? This, unlike the elongation of stems and needles, is not subject to ocular observation.

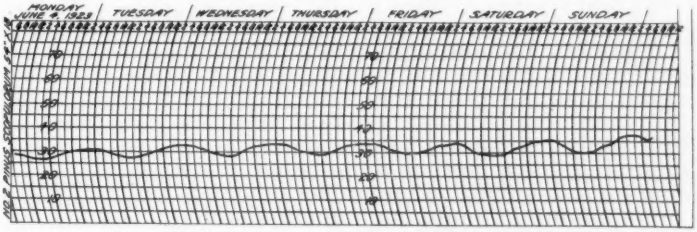


FIG. 1.—Dendrograph record of western yellow pine, June 4–11, 1923

During the summer of 1923 records of the diameter growth of two western yellow pines were maintained at the Southwestern Forest Experiment Station by means of MacDougal's dendrograph. Both of the trees are young and thrifty, one being 5.4 inches and the other 15.8 inches in diameter. The larger tree (No. 1) is in the edge of a group on a moderate slope with southeasterly exposure; the smaller one (No. 2) is more isolated and stands in a practically level situation near the north brow of a level bench about 500 feet distant.

For the benefit of those not familiar with the MacDougal dendrograph [2] its essential features are here briefly described without going into mechanical details. The instrument is held in place by a belt of wooden blocks drawn tightly around the trunk of the tree. Above this, supported by stiff wires, is a floating frame of *invar*, a metal of low temperature coefficient, encircling the trunk, but touching it only at two points. One of these points is an adjustable screw; the other, on the opposite side of the tree, is a quartz rod which slides freely in and out with every movement of the bark. On the outer end of this rod rests the short arm of an L-shaped lever whose long arm carries a pen. As the tree expands the pen is raised and as it contracts (a daily occurrence) the pen falls. The pen, in contact with a ruled sheet of paper on a revolving drum driven by clockwork, makes a continuous record of the most minute expansion or contraction of the tree.

Figure 1 shows the graph produced during a week of rapid growth. The strong diurnal movement does not reflect actual growth, but rather a swelling and shrinking which MacDougal has found to be intimately associated with the water content of the trunk. It will be noted that the maximum rise occurs at night or early in the morning, when transpiration is low. Actual growth or deposition of wood is indicated by the general upward trend of the graph. Thus, on June 4, the high point reads 31 mm. and on June 11, it reads 37 mm. Since the instru-

[1] Received for publication June 30, 1924—issued January, 1925.

[2] MACDOUGAL, D. T.—GROWTH IN TREES. 41 p., illus. Washington, D. C. 1921. (Carnegie Inst., Wash., Pub. 307.)

ment in this case was adjusted to give an amplification of 18, the growth amounts to about one-third of a millimeter in six days. A pronounced and sustained swelling, apart from actual growth, is recorded during long periods of rainy weather and a corresponding shrinkage in dry weather. Allowance must be made for these movements in computing current growth.

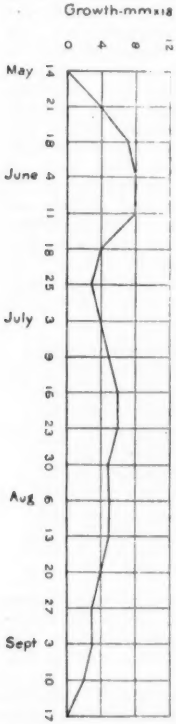


FIG. 2.—Diameter growth of western yellow pine, Southwestern Experiment Station, 1923. Tree No. 2 D. B. H., 5.4 inches. Total growth during season, 4.7 mm.

In this study the writer was interested primarily in determining at what time of the year diameter growth begins and ends. This is a matter of obvious importance in making periodic forest measurements with the object of ascertaining the annual rate of diameter growth. The relation of current growth to external factors such as temperature, moisture, and mechanical injuries offers an attractive field for research; but such a study would require vastly more attention than could be devoted to it by the writer at this time. Moreover, these relationships are being investigated by Doctor MacDougal, of the Carnegie Institution.

The instruments were installed on May 14. Tree No. 2 began to increase slightly in diameter on May 16, but No. 1 showed no signs of increase until June 1 (fig. 2). The reason for this difference is not apparent unless No. 2, because of its smaller size, was able to respond more quickly to the rising temperature. No. 1 continued to grow until about August 27, and No. 2 until about September 10. Thus the approximate periods of diameter accretion were 88 days for the larger tree and 117 for the smaller one. In both trees active growth was practically over by September 1.

It is of interest to compare the behavior of western yellow pine and other species in various localities of the Southwest. According to MacDougal, a Douglas fir, *Pseudotsuga taxifolia*, on the slopes of Pikes Peak, began growth before June 17; but a yellow pine, *Pinus ponderosa* (probably *scopulorum*), in the same locality, made no appreciable growth until August. The Douglas fir continued to grow until August 22, and the pine until September 4. *Pinus chihuahuensis* in the Santa Catalina Mountains of southern Arizona showed slight enlargements in April and the latter part of May, but made the major growth during the summer rainy season in August. *Pinus arizonica* and *Pinus strobiformis*, in the same locality, exhibited slight growth in June, followed by a cessation until the rains were in progress after the middle of July.

From the foregoing it appears that only in the case of yellow pine in northern Arizona and Douglas fir on Pikes Peak did active diameter growth begin in advance of the summer rains. Failure of yellow pine on Pikes Peak and of all the species in the Santa Catalina Mountains to grow in diameter during June is probably attributable to deficient moisture. This explanation, however, is not wholly adequate because in both of these regions, as well as in northern Arizona, the major height growth takes place prior to July 1, regardless of drought. Why the moisture should be insufficeint for diameter growth when it apparently is sufficient for height growth is not clear. This problem requires further investigation.

In studying growth by periodic measurement of standing trees, it is important that the trees, as far as diameter growth is concerned, be in a quiescent state at the time of each measurement. In Arizona and New Mexico, where growth plots have been remeasured every five years, it has been the custom to make these measurements in the fall, after September 1, assuming that the seasonal growth was finished by that date. The present study shows that this assumption was essentially correct. Investigations in southern Arizona and in Colorado indicate that in those regions, and probably throughout New Mexico, the species occurring below the Douglas fir type may also be measured in the spring and early summer until the summer rains are well in progress. In northern Arizona, however, measurements in the spring should not be made after May 15.

THE DIGESTIBILITY OF TEPARY BEANS[1]

By HARRY J. DEUEL

Formerly with the Office of Home Economics, United States Department of Agriculture

The tepary bean, *Phaseolus acutifolius*, is a native North American crop plant and has long been grown in Sonora, Mexico, and in Arizona, by the Indian agriculturists. Bailey (*1*, *p. 462–463*)[2] states that the Papago and Pima Indians cultivated tepary beans from prehistoric times and "in all probability they formed one of the principal food crops of that ancient and unknown agricultural race." The plant forms a low, trailing bush, with many slender, diffuse branches which lie close to the soil. Tepary beans are distinctly a dry-land crop grown for the beans and rarely if ever for forage. The continuous growth with formation of seed pods, which is characteristic unless frost or disease interferes, is a disadvantage if the beans are grown in the moister regions of the United States. In the dry regions it appears that tepary beans will make a larger crop on less rain than any other known species of bean. There is therefore a large range of territory in California, Arizona, and New Mexico where their culture could be widely extended if a regular market demand existed for them.

The largest extension of tepary-bean culture probably took place in 1917, when California alone produced over 150,000 bushels. The market price was not satisfactory, and later crops have been considerably smaller.

Although somewhat smaller than navy beans the tepary resembles them very closely and may be readily mistaken for them. Forty-seven color types have been isolated by the Arizona Agricultural Experiment Station, but only the white tepary beans have entered bean-trade channels of the United States. Considerable attention has been given to tepary beans and their culture and use as food at the Arizona Agricultural Experiment Station (*4*) and the California Agricultural Experiment Station (*5*, *17*).

Much is known about beans and other common legumes as food, as a result of experiments carried on by many investigators. However, in the case of the tepary bean little information has been available with respect to food value beyond the analyses showing the chemical composition the fact that this bean is an important food crop where grown, that it is wholesome, well flavored, may be prepared in much the same ways as other dry beans, and that it is held to be a nutritious and sustaining food by those who have long used it. As in the case of most dry beans soaking is a necessary preliminary to cooking, or at least it shortens the cooking period. It is interesting to note that when soaked the skin of tepary beans wrinkles more quickly than does that of navy beans. In preparing tepary beans for the table Jaffa (*17*) recommends soaking them for 15 to 30 minutes and then draining and boiling in fresh water for about three hours.

Of beans, peas, and other dry legumes it may be said that they provide protein and carbohydrates (chiefly starch) in about equal amounts and in many cases some fat. That the range is rather wide is evident when one recalls that the soybean, like the peanut, is rich in fat, but when well ripened it contains no carbohydrate in the form of starch. In these respects the tepary bean obviously resembles the navy bean rather than the peanut or the soybean. With respect to the digestibility of the more common legumes, considerable information is available, chiefly as a result of investigations carried on by the United States Department of Agriculture and its collaborators.

A series of 70 experiments on the digestibility of navy beans, red kidney beans, and several varieties of cowpeas was made at the University of Tennessee (*31*). Generally speaking, the experiments show that the legumes were as well digested and assimilated as are the coarser cereal products, and that in some instances the digestibility was as great as that of the finer grades of flour. The investigations as a whole, it is stated, demonstrate the

[1] Received for publication June 21, 1924—issued January, 1925.

[2] Reference is made by number (italic) to "Literature cited," pp. 205-208.

important place which legumes may fill in the diet as economical and palatable sources of protein, though later studies have shown that most legume proteins can not be considered complete. However, a diet containing meat, milk, eggs, and similar foods would supply this deficiency.

Digestion experiments have been made in connection with the food work of the United States Department of Agriculture with soybeans and with peanuts (*15*) cooked until soft in a household pressure cooker. The legumes formed the principal part of a simple mixed diet. The experiments show that steam-cooked peanuts were well assimilated, the coefficient of digestibility of the protein being 79.9 per cent. Large quantities of these legumes were consumed throughout the experiments, no physiological disturbances being noted. The report also points out that as regards nutritive and biological value, there is evidence to justify the belief that soybeans and peanuts are especially valuable as food in comparison with other legumes which had been similarly studied. The literature of this phase of the subject is summarized in the bulletins cited.

EXPERIMENTAL METHODS

The experimental methods used with tepary beans were those followed in digestion experiments conducted by the United States Department of Agriculture and described in earlier publications (*2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29*).

The subjects were men apparently in good health and well instructed in the experimental routine. The necessary analyses of food and feces were made by standard methods. The tepary beans used in the experiments were obtained through the courtesy of one of the correspondents of the department. The beans were prepared by soaking over night and then cooking for an hour under 15 pounds pressure. The beans were eaten with a basal diet of bread, butter, fruit, and sugar. The results of the five experiments are summarized in Table I.

TABLE I.—*Summary of digestion experiments with tepary beans in a simple mixed diet*

Experiment No.	Digestibility of entire ration				Estimated digestibility of tepary bean protein	Estimated digestibility of tepary bean carbohydrate
	Protein	Fat	Carbohydrate	Ash		
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
901	86.3	93.8	98.1	81.4	84.8	97.9
902	78.7	92.3	98.2	75.6	74.4	100.0
903	80.4	94.2	98.1	77.3	74.6	98.4
904	73.4	91.9	96.7	65.9	67.1	96.4
905	82.8	93.7	97.9	72.9	78.7	97.4
Average	80.3	93.2	97.8	74.6	75.9	98.0

The subjects ate, on an average, 70 gm. of protein, 69 gm. of fat, and 394 gm. of carbohydrate, with an energy value of 2,475 calories, per man per day. The beans supplied on an average 40 gm. of protein and 99 gm. of carbohydrate per man per day. The protein of the beans was 76 per cent utilized, which agrees closely with the value of 78 per cent for navy and red kidney beans found by Wait (*31*), and 77.9 per cent found by Mendel and Fine (*30*) for navy-bean protein. The carbohydrates of the tepary beans were on an average 98 per cent digested, which represents almost complete utilization and is somewhat higher than the value of 96 per cent found by Wait for navy-bean carbohydrates. The subjects reported that they remained in their usual normal health throughout the experimental period.

SUMMARY

A study of the digestibility of tepary beans for purposes of comparison with similar legumes shows that tepary beans are well utilized by the body and are a valuable food.

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